NVIDIA RTX 3090Ti
Team Green's fastest GPU, but is it worth buying? **PG. 74**

MONITOR MEGATEST
OLED, Mini LED, 8K. New screen tech compared **PG. 48**

YOUR NEXT LAPTOP
3 portable PCs from Lenovo & Acer reviewed **PG. 80**

MAXIMUMPC

MINIMUM BS • JUNE 2022 • www.maximumpc.com

WATERCOOLING MADE EASY

Don't liquid cool until you've read our guide!

- ✓ Screeching speed with no noise
- ✓ Overclock while staying cool
- ✓ Beautiful lighting and tubing

CORSAIR
C850

DON'T PANIC!
Build this amazing PC in a weekend
PG. 16

EVERY GPU RANKED!
2022 graphics processors compared and graded **PG. 26**

FUTURE
Digital Edition

PAPER POWER

65% of the energy demand at U.S. pulp, paper
and paper-based packaging mills is met
using renewable, carbon-neutral biomass energy.

Discover the story of paper
www.lovepaperna.org

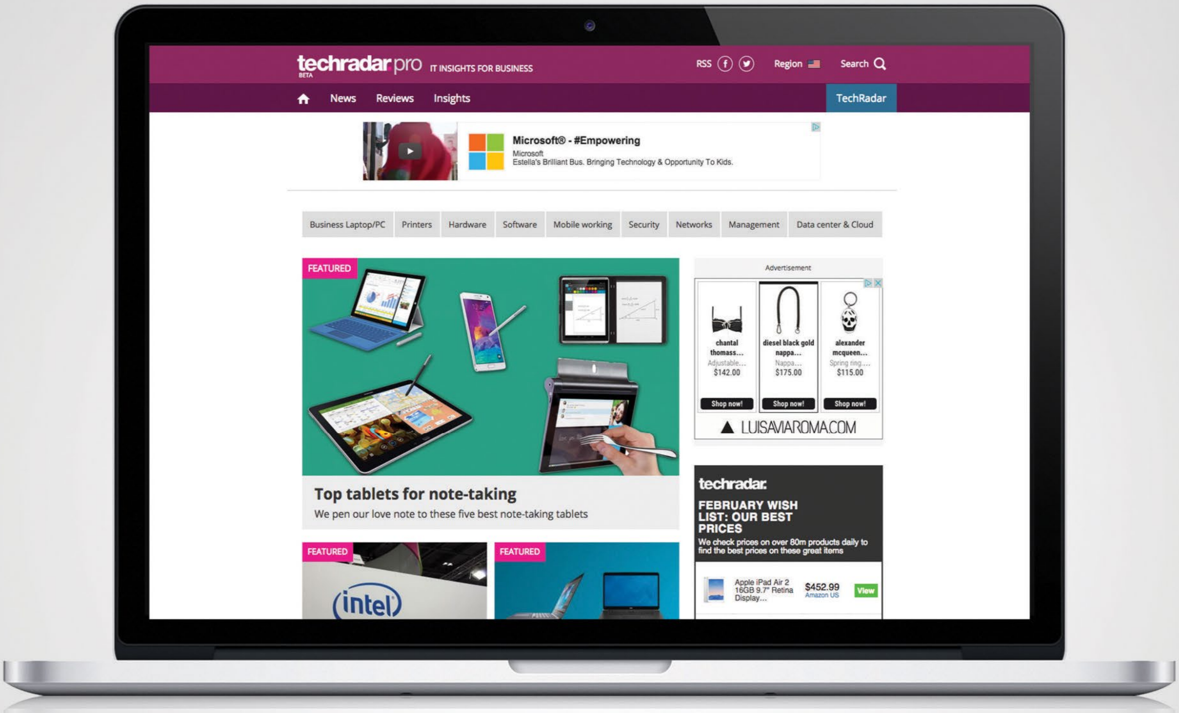
LOVE PAPER®

Source: American Forest & Paper Association, 2018

Love Paper is a registered trademark for Two Sides Ltd. Registered in the U.S., UK and other countries and used with permission.

techradar.pro

IT INSIGHTS FOR BUSINESS



techradar pro
IT INSIGHTS FOR BUSINESS
RSS
Region
Search
News
Reviews
Insights
TechRadar
Microsoft® - #Empowering
Business Laptop/PC
Printers
Hardware
Software
Mobile working
Security
Networks
Management
Data center & Cloud
FEATURED
Top tablets for note-taking
We pen our love note to these five best note-taking tablets
Advertisement
LUISAVIAROMA.COM
techradar
FEBRUARY WISH LIST: OUR BEST PRICES
We check prices on over 80m products daily to find the best prices on these great items
Apple iPad Air 2 16GB 9.7" Retina Display...
$452.99
View
intel

Best practices and solutions

Up-to-the minute news

In-depth reviews

http://www.techradar.com/pro

inside

JUNE 2022

SUBSCRIBE TODAY!
PG. 36

MAXIMUMPC
WATERCOOLING MADE EASY

QUICKSTART

8 **THE NEWS**
Intel's chip breaks records; Win11 security; AMD 6000-series goes Pro.

11 **TECH TALK**
How AMD's 3D V-Cache is giving gaming performance a huge boost.

12 **THE LIST**
Great sound for gaming? Here are our top five PC speaker systems.

A decent PC speaker system will boost your gaming, music, and streaming.

16 **12TH GEN WATERCOOLING**

26
STATE OF THE GPU-NION
How do older GPUs measure up today? We test some of the best.

38
GAME OVER
Why do some games get abandoned by their developers? Christian Guyton investigates.

48
SCREEN TECH
With OLED monitors now here, Jeremy Laird looks at the next screen tech on the horizon.

R&D

57 **HOW TO**
Get the most from Win11 Registry Editor; emulate the NEC PC-9800 from 1980s Japan; go 3D in GIMP.

66 **BUILD IT**
What if we only used components from one manufacturer in our build? Let's see, shall we...

LETTERS

14 **DOCTOR**

94 **COMMENTS**

IN THE LAB

74
ASUS RTX 3090 Ti TUF GAMING

76
VELOCITY MICRO RAPTOR Z55

90
GHOSTWIRE TOKYO

88
RAZER HUNTSMAN MINI ANALOG

87
NZXT CAPSULE

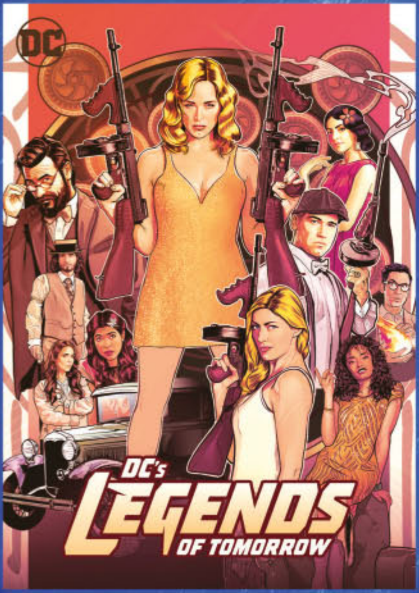
© BETHESDA

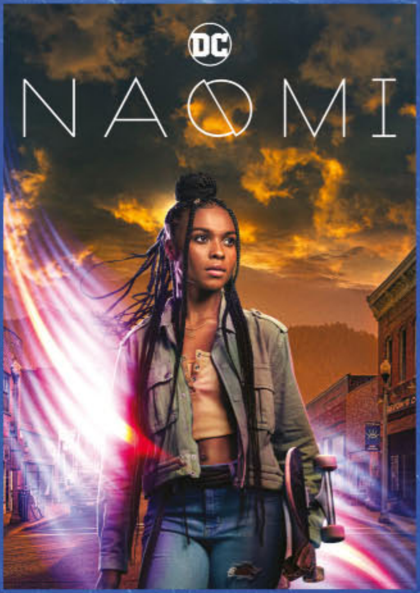
CATCH UP WITH YOUR
FAVORITE HEROES!

DC
SUPERMAN & LOIS

DC
THE FLASH

DC
BATWOMAN


DC
DC's
LEGENDS
OF TOMORROW



OWN THEM NOW ON DIGITAL

© 2022 WBEI. TM & © DC.

MAKE THE SWITCH FROM WINDOWS TO THE MOST POPULAR LINUX DISTRIBUTION AROUND!

Discover the best features of Ubuntu's default software, the best FOSS apps for you to download from the Software Centre, and then go beyond the Unity interface.

NEW
LINUX FORMAT PRESENTS
ubuntu
THE COMPLETE GUIDE
Everything you need to know to get started with Ubuntu Linux
UPDATED F
HIRSUTE HIPP
INSTALL UBUNTU
DISCOVER GREAT FEATURES
FIX COMMON ISSUES
LOVE LINUX!
100 PAGES OF UBUNTU GUIDES
100% UNOFFICIAL
ISBN 978-1-80023-528-1
FUTURE
ELEVENTH EDITION
PRINTED IN THE UK
LINUX FORMAT PRESENTS UBUNTU THE COMPLETE GUIDE ELEVENTH EDITION

ON SALE NOW

FUTURE

Ordering is easy. Go online at:

magazinesdirect.com

Or get it from selected supermarkets & newsagents

MAXIMUMPC

EDITORIAL
Editor-in-Chief: Guy Cocker
Staff Writers: Christian Guyton, Sam Lewis
Contributing Writers: Jeremy Laird, Chris Lloyd, Ian Evenden, Jarred Walton, John Knight, Nick Peers, Kris Butterill
Production Editor: Jon Crampin
Editor Emeritus: Andrew Sanchez

ART
Art Editor: Fraser McDermott
Photography: Neil Godwin, Olly Curtis, Phil Barker
Cover Photo Credits: Future PLC

BUSINESS
US Marketing & Strategic Partnerships: Stacy Gaines, stacy.gaines@futurenet.com
US Chief Revenue Officer: Mike Peralta, mike.peralta@futurenet.com
East Coast Account Director: Brandie Rushing, brandie.rushing@futurenet.com
East Coast Account Director: Michael Plump, michael.plump@futurenet.com
East Coast Account Director: Victoria Sanders, victoria.sanders@futurenet.com
East Coast Account Director: Melissa Planty, melissa.planty@futurenet.com
East Coast Account Director: Elizabeth Fleischman, elizabeth.fleischman@futurenet.com
West Coast Account Director: Austin Park, austin.park@futurenet.com
West Coast Account Director: Jack McAuliffe, jack.mcauliffe@futurenet.com

Director, Client Services: Tracy Lam, tracy.lam@futurenet.com

MANAGEMENT
MD Tech Specialist: Keith Walker
Group Editor-in-Chief: Graham Barlow
Group Art Director: Jo Gulliver

PRODUCTION
Head of Production: Mark Constance
Senior Production Manager: Matthew Eglinton
Production Manager: Vivienne Calvert
Production Assistant: Emily Wood

FUTURE US, INC.
10th floor, 1100 13th Street, N.W Washington, DC 20005, USA
www.futureus.com

INTERNATIONAL LICENSING & SYNDICATION
Maximum PC is available for licensing and syndication.
To find out more, contact us at licensing@futurenet.com or view our available content at www.futurecontenthub.com.
Head of Print Licensing: Rachel Shaw, licensing@futurenet.com

SUBSCRIBER CUSTOMER SERVICE
Website: www.magazinesdirect.com
Tel: 844-779-2822
New Orders: help@magazinesdirect.com
Customer Service: help@mymagazine.co.uk

BACK ISSUES
Website: https://bit.ly/mpcsingleissue

Next Issue On Sale 21st June, 2022

[SUBSCRIPTION DELAYS]

We rely on various delivery companies to get your magazine to you—many of whom continue to be impacted by Covid. We kindly ask that you allow up to seven days before contacting us about a late delivery to help@magazinesdirect.com

© 2022 Future US, Inc. All rights reserved. No part of this magazine may be used or reproduced without the written permission of Future US, Inc. (owner). All information provided is, as far as Future (owner) is aware, based on information correct at the time of press. Readers are advised to contact manufacturers and retailers directly with regard to products/services referred to in this magazine. We welcome reader submissions, but cannot promise that they will be published or returned to you. By submitting materials to us, you agree to give Future the royalty-free, perpetual, non-exclusive right to publish and reuse your submission in any form, in any and all media, and to use your name and other information in connection with the submission.

FUTURE
Connectors.
Creators.
Experience
Makers.

Future plc is a public company quoted on the London Stock Exchange (symbol: FUTR)
www.futureplc.com

Chief executive **Zillah Byng-Thorne**
Non-executive chairman **Richard Huntingford**
Chief financial officer **Penny Ladkin-Brand**

Tel +44 (0)1225 442 244

Guy
Cocker

BE WATER, MY FRIEND

BRUCE LEE PROBABLY wasn't referring to liquid cooling when he made his famous water quote above, but this issue of *Maximum PC* makes a strong case for water's merits in PC cooling. I have to admit, water cooling was a bit of a blind spot for me personally, having only ventured into AIO CPU coolers rather than creating any custom loops. So when Zak Storey, previously of this parish (and now of Corsair), offered the *Maximum PC* team a water cooling hands-on tutorial using the company's XH303i kit, I jumped at the chance.

Thanks to Zak's excellent tuition, I soon realized there was nothing to be afraid of. While I may not yet be the most accurate at tube bending, I was rigging up reservoirs to radiators and flushing water around the system in no time. Sam, who went on to build the final PC for this month's cover build, had a full system up and running a day and a half later. Not only that, but it looks fantastic and is deathly quiet, even under load. You too can create your own water-cooled system by following our guide on page 16. I do hope that, like me, you end up giving it a go.

Alongside Sam, I was building a machine of my own, this one made up of MSI's latest and greatest PC tech. I'd spoken to the company about some of their latest products, including the Sakira 100R case (reviewed on page 89) and its first SSD, the Spatium M480 Play. The manufacturer was offering so much of its 2022 PC component lineup that I decided to try an all-MSI Build It for this issue. I now have more MSI gear than even its own sponsored eSports teams. So, was it easier to build with just one manufacturer? Find out on page 66.

Also this month, I've been poring over more spreadsheets than even the biggest accounting nerds, thanks to Jarred Walton's epic GPU feature on page 26. Jarred has compiled specs and benchmarks of all the major graphics cards released in the past eight years, not only to demonstrate how far Nvidia and AMD have come, but also to make sure you get the right card, no matter the price point. It's the most meticulously researched feature I've seen in my many years as an editor, and full of the sort of insight you only get when you've dedicated your professional life to all things graphics tech, as Jarred has.

Meanwhile, Jeremy Laird reviews a new Alienware OLED this issue (is it worth upgrading from an LCD? Find out on page 78). This leads nicely onto his feature on page 48, covering the current state of the monitor market. Most of us have moved on to high refresh rate displays, but should we be looking at new screen tech, wider formats, more pixels, improved connectivity, or anything else? Jeremy breaks it all down and tells you what you should be looking for in your next screen.

Finally, I love getting your feedback (good or bad), so please send your thoughts to editor@maximumpc.com. Each issue, I pick a few choice queries and answer them as best I can, so turn to page 94 to see if yours has been selected. I'm also keen to get your tech questions answered by our resident expert, so if you're encountering bugs, suffering from a slowdown, or need a problem solving, get in touch with us at doctor@maximumpc.com.

Enjoy the issue!

Guy Cocker

Guy is Maximum PC's Editor-in-Chief. He built his first gaming PC in 1997 to play Tomb Raider on 3dfx, and has been obsessed with all things PC ever since.

↘ submit your questions to: editor@maximumpc.com

THE NEWS

Intel's hot new model

Overclockers break records with the Core i9-12900KS

THE CROWN for making the world's fastest gaming chip may ultimately be a hollow one, but Intel and AMD take it seriously. AMD's Zen architecture may give Intel a hard time in many areas, but that final accolade never quite falls into its grasp—and Intel is keen to make sure it doesn't. When AMD's cache-heavy Ryzen 7 5800X3D was announced, you knew Intel would answer back. It has, with the Special Edition Core i9-12900KS: a chip that only really exists to break records.

It's a classic Intel response that we've seen before: take an existing chip, carefully 'bin' it (essentially use quality control testing to pick only the most robust silicon), and you have a new halo processor, without producing any new silicon.

The Core i9-12900KS is a faster i9-12900K, up from a maximum turbo speed of 5.2GHz to 5.5GHz on two cores, a modest 5.8 percent bump. The all-core Turbo remains at 5.2GHz, while power requirements have been increased by 25W to 150W. The base clock for the performance cores has gained 200MHz to 3.4GHz, while the efficiency cores get an extra 100MHz. It also supports Intel's Enhanced Thermal Velocity Boost, and Adaptive Boost Technology. The only other real difference is the cost—Intel's recommended price is $739-749, against a regular i9-12900K's $589-599.

So what are you paying the extra for? It's that binning process that ensures you have the best version of the i9-12900 that Intel can find. Is it quick? Of course! *Far Cry 6* is an average of 12 frames faster, while *Shadow of the Tomb Raider* gains 43 frames (useful as the Ryzen 7 5800X3D would otherwise beat Intel here).

Other benchmarks are less dramatic with just a few frames at 1080p, where processor power counts, but do you game at 1080p, and what's the point of super-high frame rates? Benchmarks of over 200fps are of academic interest only. It's certainly a hot chip though, and quite literally too, as it can reach over 100°C, so you'll need capable cooling.

i9
12TH GEN
intel
CORE
SPECIAL EDITION
UNLOCKED

> The Special Edition Core i9-12900KS is a chip that only exists to break records.

CLOCK WATCHING

That meticulous binning process makes this an ideal chip for extreme overclocking. It wasn't long before one of the cores was taken to 7.45GHz. According to one overclocker called 'Splave', you can safely run any i9-12900KS to 5.3GHz on all cores with liquid cooling. Nearly all manage 5.4GHz and a few will even reach 5.5GHz.

He didn't stop there. Aided by copious amounts of liquid nitrogen, he took one chip to 7.8GHz on all cores on CPU-Z. He then took every benchmark record with it, including Cinebench R20 running at 7.1GHz using all threads. This reached a score of over 15,000. For comparison, the standard i9-12900K manages 10,000.

Do we want one? Of course, because who wouldn't want to own the world's fastest gaming chip? But it's also expensive. The recommended price is bad enough, but they're also currently going for a premium, so you're looking at $800 in the real world. The chip it was built to beat, AMD's 5800X3D, costs just $449, which is not a flattering comparison.

Running at stock speeds, the performance gain over the vanilla 12900K is minimal. But for dedicated overclockers, the KS model is a clear winner. Officially, the Ryzen 7 5800X3D doesn't support overclocking, but that hasn't stopped people from having a go. With the right motherboard, you can crank it up to 5.14GHz. Ryzens rarely make good candidates for overclocking as most are sold with little performance left to squeeze out.

AMD hasn't abandoned overclocking completely. There was a tantalizing post during a 'webinar' from Joseph Tao, Memory Enabling Manager at AMD (yes, a real job title). He claimed that with the forthcoming Zen 4 platform "we're going to try to make a big splash with overclocking", and "speeds that you maybe thought wouldn't be possible, may be possible". Sounds as though AMD is going to let people push DDR5 at least.

This fall, we'll see Zen 4 arrive from AMD and Raptor Lake from Intel, kicking off the fight once again with a new generation of processors. The 5nm Zen 4 has reached pre-production and promises a 15 percent performance bump and significantly lower power consumption. You'll also gain DDR5, PCIe 5.0 support, and possibly V-cache too.

Rumor has it that Intel's Raptor Lake will push clock speeds to 5.8GHz with its halo chip. It will also feature more efficiency cores, and a performance jump of over 10 percent above Alder Lake is expected. Given its cost and the imminent arrival of these next-gen processors, the i9-12900KS seems like a ludicrous processor in many ways, but also glorious. **–CL**

© INTEL

WINDOWS 11 UPDATES APP SECURITY

THE CATCH IS YOU HAVE TO REINSTALL WINDOWS TO USE IT

MICROSOFT has a new security system dubbed Smart App Control, which aims to make Windows as secure as possible for 'hybrid' working from home. The new system uses cloud servers to monitor an application's behavior, employing AI to spot anything potentially malicious. Sounds good, but the problem is that it won't work on any application you've already installed, so you'll need to wipe and start again. Ouch!

Having to reinstall Windows and all your applications is a big price to pay for that extra layer of security. There are other issues too, because it doesn't like unsigned or unrecognized applications. Meaning your obscure utility or elderly application will set alarms off. Until Microsoft figures out how to enable Smart App Control without a clean system and adds more control, this new feature is going to be a pain to use. **–CL**

RESTOCKED AND RELOADED

Graphics cards are back on the menu

THE GREAT GRAPHICS card drought is nearly over and to highlight this, Nvidia's marketing campaign, dubbed restocked and reloaded, is spreading the word that its GeForce RTX 30 Series cards should be in stock. In theory, you have a chance of getting cards at list price, though some opportunistic scalpers are still at large, especially for the 'hot' cards.

A quick survey of resellers shows a trend of increased availability and falling prices. The Radeon RX 6500XT and 6900 XT are now selling at just shy of list price though, on average, you can still expect to pay an extra $200. Nvidia's 40 Series cards and AMD's RDNA 3, are due at the end of the year. Both companies will want to shift the previous generation before they are rendered less desirable. It's a tough call for consumers— jump on the new stock or wait and get the next generation? At least you now have a choice. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

✓ FASTEST CARD LANDS

Nvidia's RTX 3090 Ti has launched, with a monster 10,752 CUDA GPU, 24GB of GDDR6X, 450W, and a $2,000 price tag.

✓ OPEN SOURCE BIOS

A project to build Coreboot, a configurable open source BIOS, has got it running on an Alder Lake board, albeit a Linux one.

✓ 3D MODEL YOUR STUFF

Epic did a beta test of RealityScan, which makes 3D models using smartphone images.

TRAGEDIES

✗ NO E3 THIS YEAR

Last year's E3 was held online but this year there's no show. It will return "reinvigorated" next year, organizers say.

✗ DRONE CRASHES

Amazon's $2bn drone program is struggling with "safety issues". Insiders claim delivery speed has been prioritized.

✗ SMART HOME BRICKS

Insteon shut its servers, killing all its smart home gadgets and showing how transient the kit is.

© ETHEREUM

ETHEREUM GOES GREEN

Move to proof-of-stake this year

CRYPTOCURRENCIES are volatile, rife with scams, and at the mercy of legislation, but the concept remains sound. Which currencies survive is another matter. Many will die. In fact, nearly all of them will—there are over 18,000 in existence, and a good number aren't worth the electricity used to create them. Like many technical developments before it, the original design is no longer a good fit.

At its heart cryptocurrencies, or rather the blockchain that supports the biggest of them, has a problem. It uses a proof-of-work (PoW) system. Transactions are made using complex calculations which the miners compete to finish to earn their slice. All this works neatly on a small scale, but as it gets bigger, it gets ridiculous. Bitcoin consumes enough electricity to run a small country, such as the Netherlands, for example. This is clearly unsustainable in the long term.

Enter PoS, proof-of-stake, which debuted in 2012. This replaces the near-endless number-crunching with a system in which the validators controlling transfers prove themselves by their holdings in the cryptocurrency (that's the short version, it's a bit more complicated than that). There are plenty of PoS coins about, including Cardano, which is ranked number eight in terms of its overall market value. However, Bitcoin and Ethereum currently dominate the market, and both currently use PoW.

Ethereum consumes about half the power of Bitcoin and has been working towards shifting to PoS since 2016. Its developers have tested PoS on a 'shadow fork' of the coin and, apparently, it works, albeit with a few teething troubles. They plan the full switch to PoS this year, dubbed 'the Merge'. The result is an estimated 99 percent drop in power consumption. Good news, if all goes smoothly.

All eyes now, of course, turn towards Bitcoin, the one that started it all. Here, there is reluctance: it is effectively owned by the big miners and once it moves they'll lose much of their power and be left with sheds full of unwanted hardware. However, the big PoW miners won't be missed: they consume vast resources, and our precious GPUs, to produce nothing with any physical value. Moving a digital coin from one wallet to another shouldn't require the services of a medium-sized power station. **–CL**

INTEL'S ARC ALCHEMIST

Third player joins the GPU market

IT FEELS AS THOUGH we have been waiting an age to see Intel's discrete GPUs. Development started several years ago, and we've been teased by it ever since.

Expectations are certainly high: Nvidia and AMD have carved up the graphics card market between them for decades. Intel has decided to release the mobile versions of Arc first, the A-Series Mobile, which offers a huge jump from the lackluster OEM discrete cards we've seen previously. At its heart, each Intel GPU uses Xe cores (replacing the old Execution Unit). These have 16 256-bit vector engines and 16 1024-bit matrix engines.

This equates to 128 FP16 operations per clock. More Xe cores equals more power. The media decode engine is highly capable and includes AV1 encoding (the first time we've seen this on a GPU). The software, Arc Control, looks remarkably mature too. There are five initial versions, the A350M, A370M, A550M, A730M, and the A770M. They have (in order) 6, 8, 16, 24, and 32 Xe cores. Why the names don't reflect this is a mystery, but each one also has the same number of ray tracing units.

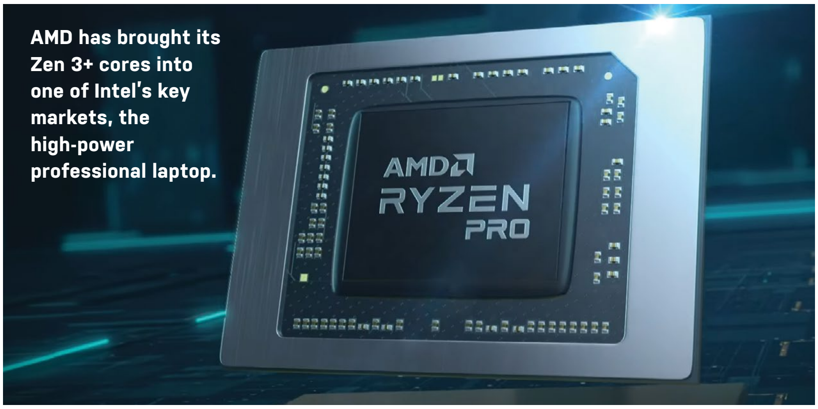
The A3s have 4GB, the A5 has 8GB, and the two A7s carry either 12GB or 16GB of memory. The memory bus is narrow (64 to 256-bit), but a decent L3 cache helps. There was some confusion over clock speeds, as Intel didn't clarify what it was quoting, as it simply states a Graphics Clock. The numbers were on the low side too, from 1,150 to 1,650MHz. It transpires this is a near-meaningless baseline speed, as actual clock speeds will be much higher (phew!). Power consumption ranges from 25W to a fairly chunky 150W.

The media engine is certainly excellent, but game performance will be the real test. The two low-end A3s are available in laptops now (in Asia first), while the A550M and beefier A7s will follow this summer. So, it's a solid start, on paper at least. Intel is slowly edging towards the graphics market, a little too slowly for our liking, but at least it's happening. Once again, we're left waiting for the main event, delayed until later this year.**–CL**

AMD's 6000 series goes Pro

AMD SEEMS DETERMINED not to let a month go by without launching something. This month, we have a new set of 6000 Pro series laptop processors. These feature Rembrandt architecture with 6nm Zen 3+ cores, and integrated RDNA 2 promising "ultimate performance for professionals". The top chip is the Ryzen 9 Pro 6950 in H (45W), and HS (35W) flavors. You get eight cores, a 3.3GHz base clock, and a boost speed of 4.9GHz, with 20MB of L2/L3 cache. Below this is the Ryzen 7 Pro 6850 and the 12-core Ryzen 5 Pro 6650, then two 'U' low power 28W versions: the Ryzen 7 Pro 6850U, and Ryzen 5 Pro 6650U. The Zen 3+ core brings DDR5 memory, Wi-Fi 6E, USB 4, and Thunderbolt support. There are also three less capable Zen 3 versions to complete the range. The 'Pro' tag means you get hardware security features, long-term support, and IT management tools that customers with sensitive data want.

As you'd expect, the launch comes with bar charts showing performance hikes, but AMD claims CPU gains over the previous Pro chips of between 1.1 and 1.3x, and a jump on the GPU side of between 1.5 and 2.1x as the RDNA 2 engine gets to work. Comparisons with Intel's nearest rivals show the usual AMD trick of strong multi-threaded scores and comparable single-thread ones. Expect laptops from the usual suspects this summer: Lenovo has ThinkPads and HP ProBooks planned. AMD has been making progress into a traditional Intel heartland: the high-end business laptop market. These new Pro chips are a serious attack on that. We know they're good, as the regular Ryzen 9 6900HS is a beast. AMD is aiming at Intel's best customers. **–CL**



AMD has brought its Zen 3+ cores into one of Intel's key markets, the high-power professional laptop.

Win11 still relatively rare

A survey of 10 million Windows systems by IT Asset Management outfit Lansweeper, has revealed that few have taken Microsoft up on its free Windows 11 upgrade offer. It puts the numbers of Win11 systems at 1.44 percent, with Win10 at 80.34 percent. There are still more people running WinXP, 7, and 8 combined than Win11.

Even data from Steam, where games systems and modern rigs are more common, puts Win11 at just 11.56 percent, with Win10 at 74.69 percent. It may be free, but with no standout features, Win11 isn't attractive enough to lure people away from their familiar Win10 desktop. Is Windows, as Microsoft once claimed, pretty much completed as an OS? **–CL**

PC sales boom over

It was ghastly for many reasons, but the pandemic led to a lot of people buying new PCs, creating a sudden boom in sales after years of stagnation. It appears that boom is coming to an end.

A survey from market research outfit International Data Corporation shows that the market has slowed down, with sales dropping over 5 percent between January and March. After two years of double-digit growth, that's an abrupt turn. Overall volumes are still respectable, with 80.5 million PCs shifted in the first quarter. As supplies increase, we should see a return to some good old-fashioned competition too, which is good news if you're in the market for a new rig. **–CL**

© INTEL, AMD

Jarred Walton

TECH TALK

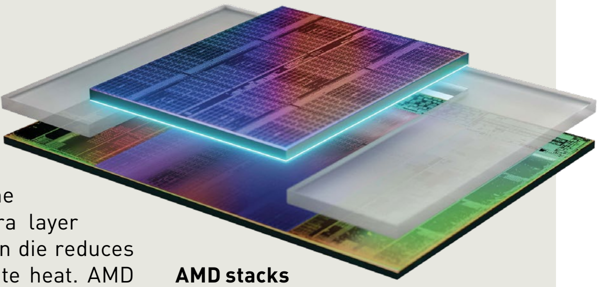
AMD 3D V-Cache Boosts Gaming Performance

WE'VE KNOWN FOR AGES that large caches can help improve performance, though larger caches can also increase latency and counteract those gains. It's a balancing act, and L1 caches have been sitting in the 32KB to 96KB range for quite some time now.

L2 caches have grown from around 128KB per core in the 90s to today's 512KB to 1MB, sometimes even 2MB, per core. But it's the L3 cache sizes that have really ballooned. Intel's various mainstream Core processors have included 8MB of L3 cache going back to the Bloomfield and Lynnfield chips in the late 2000s. In contrast, AMD chose to put 16MB of L3 cache (per eight cores) on its first- and second-generation Ryzen processors, then doubled that to 32MB of L3 (still per eight cores) on the third- and fourth-generation CPUs, Zen 2 and Zen 3. One big difference between them was that Zen 3 made it a unified L3 cache, instead of a split 16MB+16MB cache, which reduced latencies and improved performance. But AMD had bigger plans.

From the start, Zen 3's Core Complex Die (CCD) has had Through Silicon Vias (TSVs) that were intended to link up with a larger stacked cache. It was likely intended for the data center EPYC chips, but AMD has also released a consumer Ryzen 7 5800X3D with 64MB of stacked 3D V-Cache. AMD is becoming the cache company, using large caches to boost performance. The current RDNA 2 graphics architecture took the previous design and added up to 128MB Infinity Cache, which alleviated a lot of GDDR6 memory traffic and allowed a boost in performance without needing much more memory bandwidth—unlike Nvidia's use of GDDR6X.

The cache chiplet sits atop the existing L3 cache structures of the Zen 3 CCD, with a silicon shim above the hotter running CPU cores. Stacking a large cache on top of an existing design involves tradeoffs. The 5800X3D has lower base and boost clocks than the 5800X, and the extra layer of silicon on the main die reduces the ability to dissipate heat. AMD has disabled overclocking on the 5800X3D as a result, and the CPU cores get hotter while using less power and running lower clocks.



AMD stacks an extra 64MB of L3 cache on top of a Zen 3 chiplet for a massive boost in gaming performance.

© AMD

> Technically, the Ryzen 7 5800X3D now reigns as the overall fastest CPU for gaming.

Large CPU caches mostly help in applications that use a lot of memory bandwidth—if most of the code and data can fit inside the L1 and L2 caches, a massive L3 cache won't do much. While the 5800X3D shows improved performance in multi-threaded workloads like y-cruncher and 7-zip compression, the biggest beneficiary is games.

AMD claims an average boost of around 15 percent, but in our test suite, we measured a 28 percent improvement in average frame rates at 1080p compared to the Ryzen 7 5800X. Not every game will show such huge gains, and the difference between the fastest CPUs when running higher resolutions becomes negligible. However, faster GPUs are coming, which should spread things out.

Even with those potential concerns, tripling the L3 cache clearly pays dividends. Technically, the Ryzen 7 5800X3D now reigns as the overall fastest CPU for gaming. It's an incredible comeback when you consider Intel's Core i9-12900K has more cores and uses up to 85 percent more power. It held a 17 percent lead in gaming performance over the 5800X and was 11 percent faster than AMD's previous best gaming chip, the Ryzen 9 5900X. AMD has turned the tables, delivering 10 percent higher gaming performance than the 12900K, thanks to the big cache.

Intel still has better single-threaded and multi-threaded application performance, which is something AMD will look to combat with its Zen 4 architecture. Given what we've seen with the 5800X3D, it's a safe bet we'll see more Ryzen processors with 3D V-Cache. Bring on the Ryzen 9 6900X3D.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

THE LIST

THE TOP FIVE PC SPEAKER SYSTEMS

While there are plenty of headphone warriors out there, a good speaker system still has its place for gaming, music, or even just watching YouTube. There are loads of different options, from dual stereo speakers to complete surround systems, which is why we've tried to pick the best options across the various price points and categories here. But fear not, for no matter which option you choose, these systems all sound great.

5

LOGITECH Z906

A 5.1 system isn't for everyone, especially as these rear speakers are wired, but if you love the cinematic experience on your PC, this is the speaker system to go for. It's THX-certified and will decode Dolby Digital and DTS, and provide a total of 1000W of power from its five speakers and subwoofer. This is ideal for anyone running a media center PC, as it comes with various audio inputs for multiple devices, plus a remote control to switch between them. **$400, www.logitech.com**

4

LG ULTRAGEAR GP9

This wireless Bluetooth soundbar from LG is pricey but its features justify the price. As a PC speaker, it sits neatly underneath a monitor and creates stereo or virtual surround sound. But it's also a battery-powered Bluetooth speaker that can pair with a phone for five hours of party-starting music or sit under your TV. There's an app to control EQ settings and RGB lighting, plus a built-in microphone for voice chat. **$500, www.lg.com**

3

RAZER NOMMO CHROMA

This stylish offering is a 2.0 speaker system with no subwoofer, making it the best option for those short on space. The speakers are large, but they exude quality, with a rich, deep sound. There's also a headphone-out port and subtle RGB lighting around the base. **$150, www.razer.com**

2

CREATIVE PEBBLE PLUS

If you primarily use headphones but want a speaker option, the Creative is a fantastic choice. It's a full 2.1 system with a separate subwoofer to drive the bass. The two pebble speakers are small, but sound crisp and go relatively loud. They're powered by USB, saving plug sockets at your desk. **$50, www.creative.com**

1

LOGITECH G560

These Logitech speakers look great and sound fantastic, thanks to serious volume levels and a bulky subwoofer that creates an immersive soundstage. The RGB lighting is based on Logitech's Lightsync system and it also works with your phone over Bluetooth. **$240, www.logitechg.com**

© LOGITECH, LG, RAZER, CREATIVE

Jeremy Laird

TRADE CHAT

The problem with the PC is power…

AS THE FANS INSIDE my Intel eight-core laptop spooled up to their customary mini-hurricane mode, it reminded me that the PC has a major problem with power efficiency. I had a couple of Chrome windows open running 10 tabs each. That's pretty much all it takes for my laptop to freak out now.

Admittedly, this laptop is powered by Intel's 11th gen rather than 12th gen CPU architecture. But 11th gen chips are still built on Intel's latest 10nm production process. And if there's one thing that 12th gen Alder Lake sucks at, it's power efficiency. Give the 12900K desktop model a hammering and it guzzles as much as 300W while hitting 100°C.

Not that Intel is alone in producing silicon power hogs. Nvidia's Geforce RTX 3090 can breach 350W, while the new 3090 Ti can hit over 500W. AMD's current graphics boards are little better. The Radeon 6900 XT will happily suck down 325W or so.

Next-gen GPUs due later this year are expected to be even worse. The Nvidia GeForce RTX 4090 is rumored to be a 600W board. A mooted 4090 Ti variant could possibly come in above 800W. Now imagine a scenario with a maxed out 3090 Ti running in the same rig as an Intel 12900K CPU also under full load. The total system power consumption would be getting close to the recommended 1,440W limit for continuous power from a standard US wall socket.

It's the sort of power consumption that gets you thinking about environmental issues, not to mention cost issues. I mean, have you seen oil and gas prices lately? It's a parlous state of affairs given chip manufacturing processes continue to advance. That next-gen Nvidia 40 series GPU is expected to be produced on TSMC's latest 4nm node, for instance. It's hard to understand how things have gotten so bad.

> The ever-increasing power consumption of the latest CPUs and GPUs cannot continue.

Nvidia's new RTX 3090 Ti inhales a ludicrous 500 watts

© NVIDIA

It doesn't have to be this way—and, yes, I'm going to mention Apple silicon. The latest MacBook M1 Air makes every x86-powered PC laptop look ridiculous. Its single-core performance is as good as anything this side of Intel Alder Lake. With four performance cores and four efficiency cores, the multi-threaded performance isn't bad either. It does this in a slim chassis with no active cooling that barely gets warm or throttles.

It uses about 30W totally strung out, but that's the whole laptop, not just the M1 chip. As for the higher-performing M1 chips, they are just as impressive. The M1 Max fitted to a 16-inch MacBook Pro hasn't quite got the multi-threaded grunt of, say, an Intel Core i9-12900HK mobile CPU. But it's competitive in most benchmarks. And if there's a 12900K-powered laptop that has even half the battery life of the MacBook, I haven't seen it. Most have a third or a quarter of the battery life, or even worse.

At the core of the problem on the CPU side of the equation is the x86 ISA. There's no avoiding the fact it's both ancient and wasn't originally conceived with power efficiency in mind, unlike the ARM instruction set used by Apple silicon that was all about efficiency. Of course, until recently, that focus on efficiency has seemingly prevented an ARM chip from competing on pure performance. Clock-for-clock, in the single-threaded workloads the cores in M1 are more powerful even than Alder Lake. If Apple starts cranking up the clocks and chucking a load of cores in a future Mac Pro, it should be interesting.

Anyway, that's not to say Apple is going to take over the world and replace our beloved PCs with Macs. But the PC does have a power problem that desperately needs solving. The ever-increasing power consumption of the latest CPUs and GPUs cannot continue. If x86 can't up its game, maybe it's finally time that long-mooted transition from x86 to ARM for the PC actually happens.

Six raw 4K panels for breakfast, laced with extract of x86… Jeremy Laird eats and breathes PC technology.

DOCTOR

THIS MONTH THE DOCTOR TACKLES…

> BSOD-plagued PC
> CPU for Windows 11
> Rekindle old magic

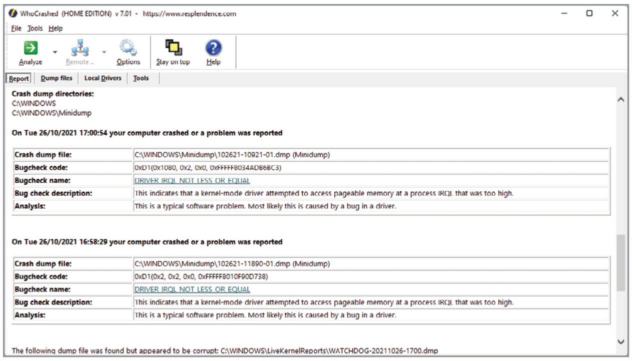
Strange BSODs

Ever since Windows 11 was announced, I've started experiencing the notorious Blue Screen of Death (BSOD) at least once a day. I'm still running Windows 10 Pro 64-bit and have kept up to date with Windows Updates. In fact, that's often when I get a BSOD crash—just checking for updates.

Is this Microsoft's new policy to force us off Windows 10? According to Microsoft, my laptop will support Windows 11, so I assume it should continue to support Windows 10 until the Windows 10 end date.

I've thought of switching to Linux and even looked at Apple briefly. If I do switch, I don't want anything to do with Microsoft, but I can't find anything that works like Outlook, so I'm stuck.

Which Linux is Microsoft not involved in? I know you guys often recommend Ubuntu. Since I have Ubuntu on Windows, I'm assuming Microsoft is involved. Is this true? Can I extract myself from Microsoft operating systems? And can Linux guarantee to stay up and running like real UNIX systems do? Or will I have to live with constant crashes?



Crash dump directories:
C:\WINDOWS
C:\WINDOWS\Minidump

On Tue 26/10/2021 17:00:54 your computer crashed or a problem was reported

Crash dump file:	C:\WINDOWS\Minidump\102621-10921-01.dmp (Minidump)
Bugcheck code:	0xD1(0x1080, 0x2, 0x0, 0xFFFFF8034ADB6BC3)
Bugcheck name:	DRIVER_IRQL_NOT_LESS_OR_EQUAL
Bug check description:	This indicates that a kernel-mode driver attempted to access pageable memory at a process IRQL that was too high.
Analysis:	This is a typical software problem. Most likely this is caused by a bug in a driver.

On Tue 26/10/2021 16:58:29 your computer crashed or a problem was reported

Crash dump file:	C:\WINDOWS\Minidump\102621-11890-01.dmp (Minidump)
Bugcheck code:	0xD1(0x2, 0x2, 0x0, 0xFFFFF8010F90D738)
Bugcheck name:	DRIVER_IRQL_NOT_LESS_OR_EQUAL
Bug check description:	This indicates that a kernel-mode driver attempted to access pageable memory at a process IRQL that was too high.
Analysis:	This is a typical software problem. Most likely this is caused by a bug in a driver.

The following dump file was found but appeared to be corrupt: C:\WINDOWS\LiveKernelReports\WATCHDOG-20211026-1700.dmp

Use WhoCrashed to help troubleshoot BSODs.

© WHOCRASHED

In case these BSOD crashes have anything to do with hardware, I'm running an Intel Core i9-9900K CPU with 32GB RAM, 1TB internal drive plus 10TB external hard drive. Windows 10 Pro is version 21H2. I've also got an additional 8TB external hard drive for backup. I use Code42 CrashPlan for backups, both offsite and to my 8TB drive. I run a homegrown script to zip my script library weekly as a backup, which is then copied to my C: drive.

Please help me by explaining the direction you think I should go. Most of my customers run AIX, so I don't need Windows, but I would like to continue using Outlook. **—Frank Posa**

THE DOCTOR RESPONDS: Your BSODs won't be the result of some Microsoft conspiracy, Frank. It's likely to be a coincidence when the issue began, but you don't say what you've done to troubleshoot the problem. Without tackling the underlying cause, you will continue to be plagued by these BSODs.

Without knowing more about the errors you're getting, it's impossible to offer anything other than generic advice, such as following the info in the Save Our Systems feature in our February issue, downloading and running the free version of the Windows Repair tool (www.tweaking.com) to perform basic system checks, including chkdsk on your hard drives and SFC on Windows system files. Also, test your RAM—a common cause of random BSODs—using Memtest86 (www.memtest86.com/memtest86.html) rather than the built-in Windows Memory Checker tool.

If all these check out, you'll need to find out more about the BSODs you're suffering. The solution here is to install the free version of WhoCrashed (www.resplendence.com/whocrashed), which will provide more detail about crashes, with the hope of identifying an underlying cause and possible solutions. Also, consider whether now is the time to bite the bullet and reinstall Windows from scratch to create a factory fresh, stable installation to work from going forward.

As for Microsoft's links to Ubuntu, consider it and Canonical (Ubuntu's developer) as frenemies, nothing more. Ubuntu isn't the only shell you can get for Windows; both Debian and Suse are also available, for example. We like Ubuntu because it's well supported and geared towards those with less experience using

↘ submit your questions to: doctor@maximumpc.com

Linux—choose the LTS branch if you favor stability over new features. If you dislike Ubuntu's Gnome desktop, try an Ubuntu variant such as Mint (https://linuxmint.com/) or Elementary (https://elementary.io/). Create live media to explore each environment without committing to a full install.

Regarding the Outlook sticking point, if you're happy with Outlook's web-based version (https://outlook.office.com) then try a desktop wrapper such as Prospect Mail (https://github.com/julian-alarcon/prospect-mail). If you're looking to replicate the desktop version of Outlook, your biggest issue will be accessing an Exchange server. Both Evolution (https://wiki.gnome.org/Apps/Evolution) and Thunderbird (www.thunderbird.net) should work with Exchange servers, but if you're struggling, look at DavMail (http://davmail.sourceforge.net/), which can act as an intermediary between Exchange and your Linux email app.

Lazesoft rescue issue

Lazesoft Recovery Suite was recommended in your March 2022 issue, so I downloaded and installed the app on a USB flash drive—the problem is that it doesn't boot. Three other flash drives containing Windows 10, Windows 11, and my backup/restore/clone app all boot perfectly.

Lazesoft installed three folders and two files on my USB flash drive. The folders are: boot, efi, and sources, and the files are bootmgr, and bootmgr.efi.

I can't understand why the app won't boot. Any advice?

—Jerry Bell

THE DOCTOR RESPONDS: We've tested the Lazesoft emergency boot disk extensively enough to know there's no known compatibility issue with it, despite the fact it hasn't been updated since Windows 11 was released. We had no problems creating the disk on our Windows 11 test system using the default settings, and it worked fine regardless of whether Secure Boot was enabled, and whether CSM was disabled.

We contacted Jerry and discovered he was able to get the rescue disk working on his Dell Inspiron 5585 laptop, but only after entering his BIOS and disabling both the Firmware TPM setting under Security and UEFI option under Boot. He was keen not to leave these settings like that, so reverted to their defaults. The key thing here is that he's found a way to get the Lazesoft rescue disk working should he need to use it.

A search online reveals that Dell's Inspiron laptops are notorious when it comes to getting certain types of boot disk to work. Many won't work at all with GPT-partitioned flash drives for example. If Jerry wanted to dig deeper, he could try creating the Lazesoft recovery disk as an ISO file, then using a tool like Rufus (https://rufus.ie) to create a bootable flash drive from it. Rufus allows you to control all aspects of the drive setup and formatting process—experiment with the partition scheme (MBR or GPT), target system (BIOS or UEFI), and file system (choose FAT32) settings to see if you can get a bootable drive to work with your system without having to tweak the UEFI first.

Win11-compatible CPU

My wife uses an HP Pavilion 590-p0024 PC powered by an AMD Ryzen 3 2200G and 8GB RAM. Can I upgrade its processor to one that will support Windows 11, as this appears to be the only block? She uses this computer for working with MS Office apps and photos with ACDSee and feels left out when she sees my upgrade. I cannot convince her that upgrading will not gain that much for what she does.

—Edmund 'Ted' Shaw

THE DOCTOR RESPONDS: The HP Pavilion in question is powered by a Sunflower motherboard, and a glance at its specifications online (https://support.hp.com/us-en/document/c05939208) reveals that TPM 2.0 support is built into the board. However, the stumbling block here was Microsoft's decision to exclude first-generation Ryzen chips (which include the Ryzen 3 2200G and Ryzen 5 2400G). This means only two processors on the Sunflower's compatibility list support Windows 11: the Ryzen 5-2600 and Ryzen 7-2700.

Although the Ryzen 7 has more cores and threads—8 and 16 compared to 6 and 12 on the Ryzen 5—the pair are closely matched, and indeed the Ryzen 5's slightly faster clock speed (3.4GHz to the Ryzen 7's 3.2GHz) gives it the edge in several benchmarks. At the time of writing, both are still available online, the most cost-effective way to get them is through AliExpress (www.aliexpress.com) where the Ryzen 5 costs around $120 and the Ryzen 7 around $160. Ted will also need a discrete graphics card but plans to reuse an old ATI Radeon card. So long as it supports Windows Display Driver Model (WDDM) 2.0 or later, and DirectX 12 API or later, he should be fine.

Looking for inspiration

I've been wondering about programming: if there's a piece of the IT universe that I've never explored, this is it. Maybe it would allow me to restart from scratch and find new mysteries, connections, and discoveries behind those strings that, at the moment, are obscure to me. Do you think that would help?

There's a huge choice, so is there any direction you would suggest, especially now that you know my tastes? After all, I loved MS-DOS, and I still enjoy any moment I can put my hands on some CMD, PowerShell, Terminal, or similar window.

—Nicola Di Pietro

THE DOCTOR RESPONDS: This was part of a longer letter from Nicola, who is looking to rekindle his love and enthusiasm for computers. As he identified programming as a potential outlet, the Doc recommends looking at the Raspberry Pi (www.raspberrypi.com) ecosystem. The Pi 400 combines computer and keyboard in a way not seen since the days of 16-bit machines and the barebones Pi 4 Model B lets you customize a PC from scratch.

More importantly, the Pi encourages you to try out new things—there are a myriad of hardware projects Nicola could explore. However, given his love of the command line and desire to program, perhaps the greatest gift would be an introduction to the world of Python (www.python.org), which underpins so many Pi projects (hardware and software).

This has been selected by the Raspberry Pi Foundation as its primary language, so comes preinstalled with the Raspberry Pi OS. Visit https://projects.raspberrypi.org/ to see if inspiration strikes. ⏻

Rekindle old computing magic with the Raspberry Pi.

© RASPBERRY PI FOUNDATION

12TH GEN WATERCOOLING

Mixing PC components with water coolant, pipes, and fastenings? *Sam Lewis* goes in at the deep end

LIQUID COOLING MACHINES are the show cars of the PC world—striking setups that grab your attention. However, the benefits of switching to a water-cooled system go way beyond just the aesthetics—it can cool down your build while performing at a whisper-quiet volume. There are some downsides to water cooling your build though. It gets complex, so there's more planning involved than in your regular PC build, but we're going to show you that anyone can give it a go.

There are two types of water cooling setups, soft tubing, and hard tubing—the latter requiring heating and bending pipes into position. Mixing fundamental plumbing with PC building might sound like the stuff of night terrors, but it's not that scary once you get into it. We're going straight into the deep end, but we'll make things easy to follow. Even I, a newbie water cooler, was able to piece my first system together with only a couple of days and a little trial and error.

The resulting system is packing some sweet components, including Intel's i9-12900k for the brain, Asus's ROG STRIX GeForce RTX 3080 OC for the heart, and Corsair's liquid cooling kit for the veins. The machine is housed in Corsair's striking 5000T case, with its RGB strips matching our fans, cooler lighting, and LC100 case lights from Corsair. Hopefully, this colossal rig will run silently, with low temperatures, and with no hiccups. Let's dive straight in.

WATERCOOLING PC INGREDIENTS

PART		RETAIL $	STREET $
CPU	Intel Core i9-12900K	$589	$610
GPU	Asus ROG Strix GeForce RTX 3080 OC 10GB	$850	$1,229
RAM	32GB (2x 16GB) Corsair Vengeance DDR5-5200	$324	$324
Mobo	MSI MEG Z690 UNIFY Gaming Motherboard ATX	$480	$480
OS Storage	2TB XPG GAMMIX S70 M.2 PCIe 4.0 SSD	$329	$239
PSU	NZXT C850 80+ Gold PSU	$129	$129
Cooling Kit	Corsair Hydro X Series iCUE XH303i RGB Pro Custom Cooling Kit	$499	$499
Radiator	Corsair Hydro X Series XR5 360mm Water Cooling Radiator Black	$80	$80
90° Cooling Fittings	Corsair Hydro X Series 90° Rotary Adapter Twin Pack x4	$108	$108
14mm OD Fitting	Corsair Hydro X Series XF Hardline 14mm OD Fitting Four Pack x1	$27	$27
GPU Water Cooling Block	Corsair Hydro X Series XG7 RGB 30-SERIES STRIX GPU Water Block	$169	$169
Case Reservoir Pump/Combo	Corsair Hydro X Series XD5 RGB Pump/Reservoir Combo	$169	$169
Case	Corsair iCUE 5000T RGB Tempered Glass Mid-Tower ATX	$399	$399
Case lights	Corsair iCUE LC100 Case Accent Lighting Panels - Starter Kit	$129	$129
OS	Windows 11 Home Key	$20	$20
TOTAL		**$4,301**	**$4,611**

PRICES CORRECT AT THE TIME OF PRINTING

BUILD IT PG.19

GEFORCE RTX
C850

CPU

INTEL CORE I9-12900K

WWW.INTEL.COM

The 12900K is a mighty speedy chip and features a big architectural change for Intel. With a hybrid form containing 16 cores equally split between performance-oriented foreground cores and background efficiency cores, it aims to achieve the best of both worlds. The chip includes out-of-the-box, one-click overclocking that can achieve frequencies of up to 5.2 gigahertz and is a super-solid processor to fit into our build.

- *RRP: $589*
- *Street price: $610*

GPU

ASUS ROG STRIX GEFORCE RTX 3080 OC 10GB

WWW.ASUS.COM

With prices falling on GPUs, it's a better time to pick one up. This OC variant of Asus's RTX 3080 is a very powerful graphics card that will be more than enough to push this machine to gaming excellence. It features 10GB of GDDR6X and in OC mode it has speeds of 1935 MHz. The GPU also has an impressive heatsink, although we'll be upgrading this via liquid cooling.

- ***RRP: $850***
- ***Street price: $1,229***

STORAGE

XPG GAMMIX S70 2TB M.2 PCIE 4.0 SSD

WWW.XPG.COM

For our primary storage, we've chosen XPG's super speedy GAMMIX S70 SSD, specifically the 2TB version. This has great sequential performance and a quad-lane PCIe 4.0 interface making it a more than capable storage hub for this liquid-cooled PC. In hindsight, we should have opted for the blade variant without the pre-installed heatsink, but it's ok!

- ***RRP: $329***
- ***Street price: $239***

CASE

CORSAIR ICUE 5000T RGB MID-TOWER ATX

WWW.CORSAIR.COM

Go big or go home? Well, let's just say we didn't go home. When liquid cooling for the first time, the more room the better. This Corsair 5000T case has more than enough room for efficient airflow, heat dissipation, and space to maneuver inside. It does all this without looking like a slab. The case features iCUE lighting strips around and in the white color scheme, it should pair up nicely with our water cooling gear.

- *RRP: $399*
- *Street price: $399*

CASE LIGHTS

CORSAIR ICUE LC100 CASE ACCENT LIGHTING PANELS STARTER KIT

WWW.CORSAIR.COM

To finish things off in the case, we're trying out Corsair's new iCUE LC100 accent lights. These magnetic modular panels stick together and connect to the SATA cable from the PSU. You can create 3D shapes or mold them around your case to add a bit more glow to your build.

- *RRP: $129*
- *Street price: $129*

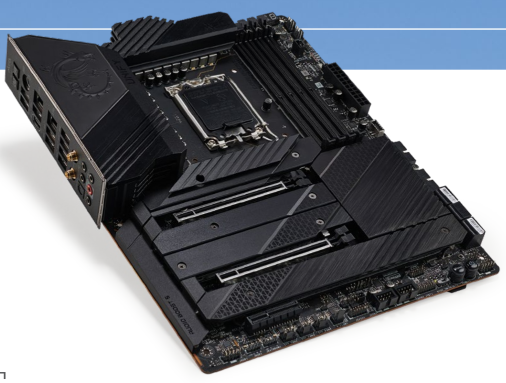
MEMORY

32GB (2X16GB) CORSAIR VENGEANCE DDR5-5200

WWW.CORSAIR.COM

Visually, not much has changed from DDR4 to DDR5, but is that such a bad thing? We're excited about the potential the new generation has to offer. These Corsair Vengeance sticks can reach speeds of up to 5200MHz and 32GB, making it a powerful kit of RAM to add to the build.

- ***RRP: $324***
- ***Street price: $324***



MOTHERBOARD

MSI MEG Z690 UNIFY GAMING MOTHERBOARD ATX

WWW.MSI.COM

MSI's monster ATX mobo has a plethora of top-end connectivity. With lightning Gen 5 PCIe, DDR5 support, and five M.2 connectors, you can spec this board up to extreme levels. If you're going for a 12th gen Intel chip and you're switching from DDR4 to DDR5, this mobo makes a great choice for futureproofing.

- ***RRP: $480***
- ***Street price: $480***

PSU

NZXT C850 80+GOLD PSU

WWW.NZXT.COM

To keep all this power under control, we have NZXTs C850 PSU to add to our build. This 850W 80+Gold power supply is an efficient unit to maintain all of the high-performance components we have, plus the liquid cooling reservoir and pump combo. With a modular design and plenty of connections around the back, it's a well-rounded PSU.

- *RRP: $129*
- *Street price: $129*

COOLING KIT

CORSAIR HYDRO X SERIES XG7 RGB 30-SERIES STRIX GPU WATER BLOCK

WWW.CORSAIR.COM

One thing that's unfortunately not included in the cooling kit is a block for the GPU. Of course, these vary from GPU to GPU, so you need to be a lot more specific when ordering one—as we found out the hard way when we ordered the wrong block. Schoolboy error!

It doesn't look as nice as the XD5 clear version we initially chose but then again, that would have been useless. This block should keep our hefty GPU running cool under heavy stress, and we're excited to see it in action.

- *RRP: $169*
- *Street price: $169*

COOLING KIT

CORSAIR HYDRO X SERIES ICUE XH303I RGB PRO CUSTOM COOLING KIT

WWW.CORSAIR.COM

For our main bulk of the liquid cooling, we've opted for Corsair's XH303i custom cooling kit in white. We're also using another XR5 360mm radiator and a few more fittings to complete our liquid cooling but this kit comprises all you'll need to make a custom loop. You get an XC7 RGB PRO CPU block, XR5 360mm radiator, the XD3 pump/reservoir combo, three SP120 RGB elite fans, and a range of fittings and tools to get the job done. The only other thing you'll need is a heat gun for bending the hard tubing.

- ***RRP: $499***
- ***Street price: $499***

INTO THE LIQUID LOOP

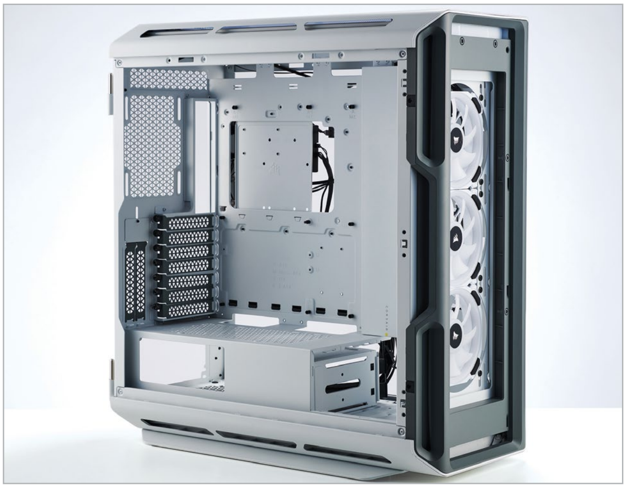
FIRST TIME LIQUID COOLING? WE WON'T LEAVE YOU HIGH AND DRY

LENGTH OF TIME: **4-5 HOURS**

LEVEL OF DIFFICULTY: **MEDIUM**

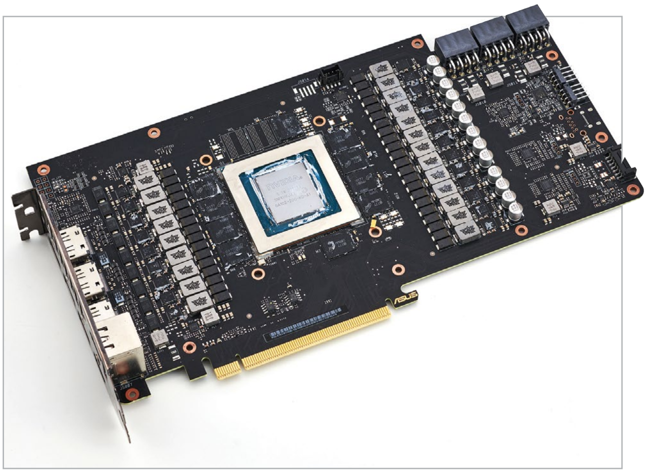
1 DISMANTLING

RIGHT PEOPLE, we need as much room as we can possibly get out of this case. Liquid-cooling can be a fiddly operation with tight angles and impossible gaps. To make life easier, we start off by taking as much of the case apart as possible. You may be thinking, "well why have you left the front radiators in?" These work in our favor as we'll be installing a 360mm radiator behind them. Other than that, the side panel wing doors come off with one screw holding each one. The front panel pops off with a gentle pull from the bottom and the same applies to the top panel. Now that's stripped, on to some more tearing down.



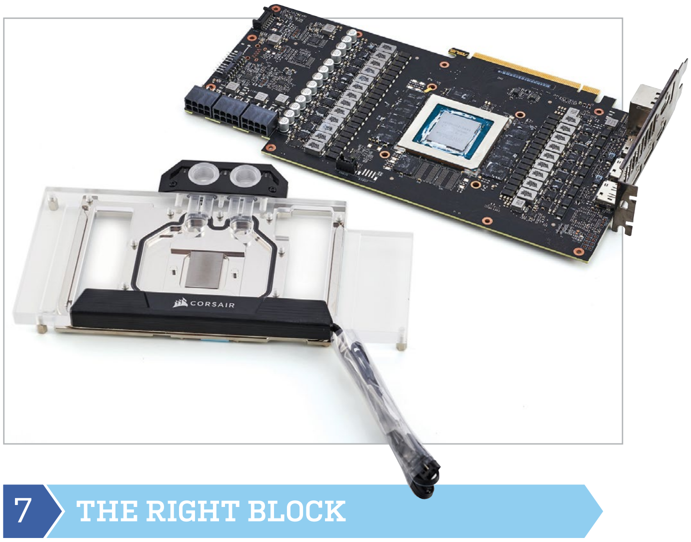
2 GPU TEARDOWN

WE USUALLY FOCUS on the GPU later on in the build but we need to do some prepping now to get it ready for some liquid cooling. Yep, on paper it's scary, and if you do this it will probably void the warranty on your card, but it's actually not as worrisome as you might think. We're after the bare bones of this GPU so to start off with, we need to remove the screws that hold the casing on. Then we remove the GPU bracket that sits around the processor on the board. Be careful when doing this as it's spring-loaded so loosen a corner gradually at a time. With all the screws aside, we can take the mighty fans and heatsink unit off our ASUS 3080 OC but unfortunately, we had to then set this aside for now.



3 THE WRONG BLOCK

ADMITTEDLY, we initially ordered the wrong GPU cooling block here. The one we initially chose was Corsair's XG5 GPU block, and it took us all the way until stripping the GPU to figure that out. After trying to line up the screw holes, I started to feel like I was in over my head a little on this build. The incorrect Corsair GPU cooling block also looks sleeker than our replacement part, thanks to its mainly transparent design, but looks aren't everything and we'd always opt for the version that fits, of course. Luckily, we managed to order the correct Corsair Hydro X Series XG7 block for next-day delivery and parked this issue until later. We'd ordered the non-OC variant for our ASUS Strix 3080 GPU and well, it just didn't fit.

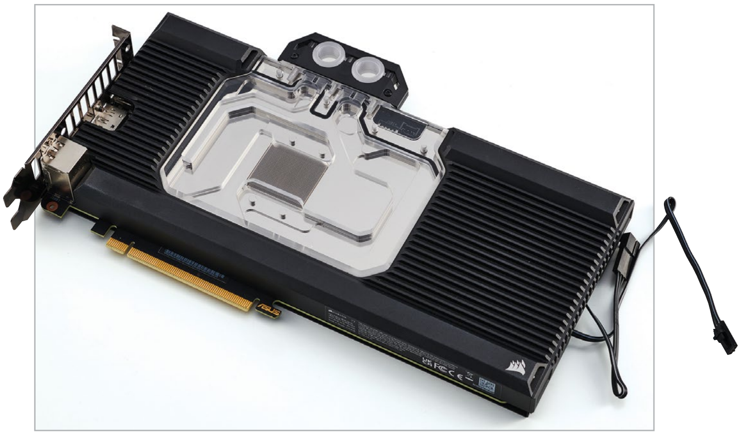


6 IN POPS THE MOBO

NOW THAT THE CPU, CPU cooling block, and SSD are installed, we can put the motherboard into the case. We know what you are thinking, "what about the RAM"? That's one of the easier things to install in this build, so we're saving that until later to give us as much clearance in the build as possible. Back to the motherboard, lay the case down flat, and then slot the mobo's I/O shield into the gap in the back of the case first. Once this is in place, rest the motherboard down into the case and align the screw holes. Then with a long neck screwdriver, screw down the mobo into the case starting with the corner screws. It's not always necessary but using all the screws possible ensures that the motherboard is well grounded to the case.

7 THE RIGHT BLOCK

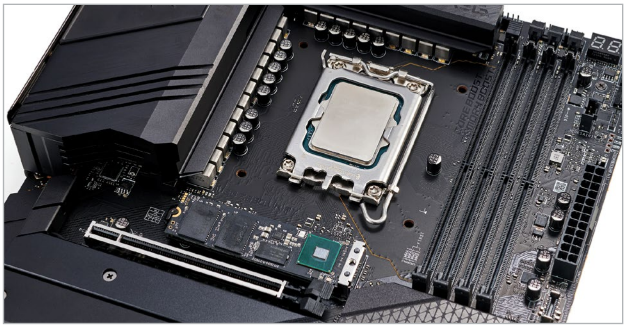
WITH A BIT OF MOVIE MAGIC, our XG7 Strix GPU cooling block arrived and so we could begin with the next part of our RTX 3080 OC. We already have the mighty fans of the 3080 OC and plates stripped off so we can add our newly acquired GPU block in place. Try to remove as much of the pre-existing thermal padding as possible from the original GPU board as the new GPU water block should have some pre-applied thermal paste, but of course, do check before securing it down. Talking of which, securing it down in place was a simple process using the screws that came with the kit, just remember there are just a lot of them. The only thing you have to do differently to fit the block on the GPU is to hang the I/O shield off a table edge so that it can be secured and aligned.



4 BRAIN AND STORAGE TIME

GPU DRAMA ASIDE, we turned our attention over to the CPU and SSD installations. Again, this involved some tearing down too, on our SSD that is. The XPG GAMMIX S70 we picked looks great but unfortunately, we had to take off its heat shield as it didn't fit flush on our board, plus the mobo has a pre-installed heat sink. To do this, there were two tiny screws holding the top part of the casing on, and then we had to use a gentle bit of heat gun magic to separate the bottom section.

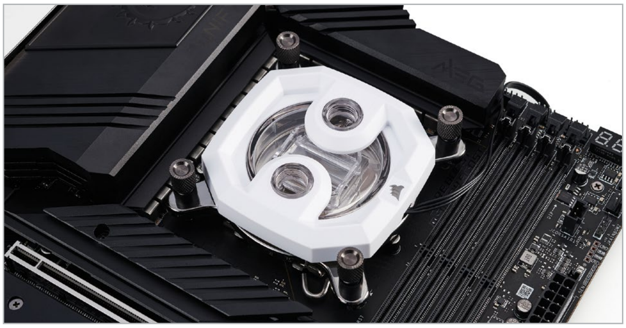
Then, the SSD slides into the port at around a 30-degree angle and a tiny screw swivel fastens it into place. As for the CPU, this went swimmingly, as these 12th Gen chips with the new rectangular design are easier to fit than ever. You still need to align the corner with the one on the motherboard of course, but at least it removes two points of failure. To open the CPU, raise the retention arm from under the hook and lift up, rest the CPU onto the pins and then lower the arm back under the hook.



5 PROCESSOR COOLING

ONCE THE CPU IS IN PLACE, we need to add our first liquid cooling component. For our CPU cooling block, we'll be using the Hydro X Series XC7 RGB PRO from the Corsair kit we have for this rig. Whatever CPU block you're using, always make sure that it's compatible with your socket type, in our case, that's an LGA 1700 socket for our 12th gen Intel chip. This step isn't too different from a usual AIO block.

Start off with aligning the corresponding bracket to the back of the motherboard. What is different is the orientation of the pump, you'll need to make sure that you'll be able to join up your tubing with the inlet/outlet holes on the CPU block further on in the build. When planning, organize your build out on a piece of paper. After you've figured out your plan, align the block to the CPU and then tighten the screws corner to corner to get an even tension. Our block came pre-applied with some thermal paste, but it's always good to check—if it looks a little small, add a bit more.



8 TOTALLY RAD

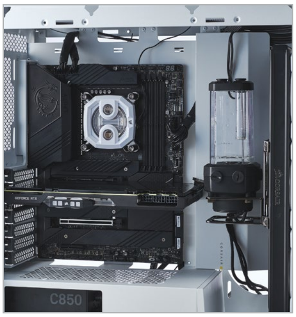
AGAIN, we're setting the GPU aside and turning our attention to the radiators. We've got two contrasting Corsair Hydro X Series XR5 360mm rads, one white and one black. We had intended to have the tubing come out the front end of the top radiator but noticed that it would be a tight fit to get our pipes to angle that way. So, we changed our plan and had the pipes for the top radiator come out towards the rear end of the case. For the front radiator, we placed the inlet/outlet valves at the bottom of the case.

Another change we had to adjust for was the three SP120 fans in the XH303i cooling kit. We were going to install these inside the radiator to shine some of the RGB glow around, but this left no clearance for the top of the mobo and meant we'd have to go crazy with the fittings. Apart from that, installing the radiators was a breeze using the long threaded screws that came in the kit. The front-facing fans act as our intake and the top fans, with the faces aiming inside the case, are used for the PC's exhaust.

9 ADDING THE POWER SUPPLY

ONE COMPONENT we can install that won't get in the way of our cooling system is the PSU. This NZXT C850 unit has more than enough wattage to power this rig and the cooling pump. As it's a modular design, we only keep in the necessary cables and make sure they are all secure first before installing them in the case. To fit the PSU, align the screw holes with the ones on the case. Annoyingly, these were fairly tight but we managed to screw it in safely and with the fan of the PSU facing downwards.

10 GPU & RESERVOIR PUMP INSTALL

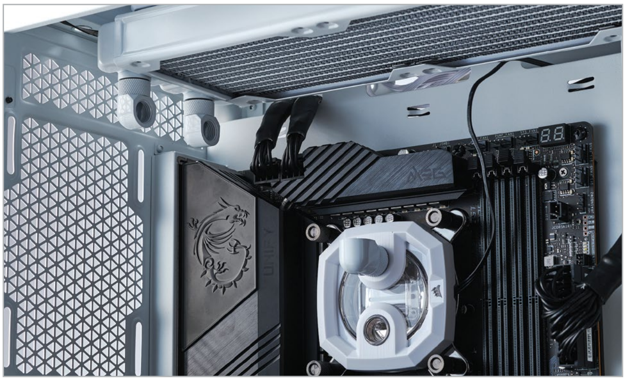


BACK INTO THE MAIN PART of the case, we kick things off by installing our water-cooled GPU into the top PCIe slot. First, we need to remove two shields from the back of the case for the I/O to fit in place. After unscrewing these plates, keep the screws nearby as we'll be using them to secure the plate back into place. Making sure the clip on the PCIe slot is open, we can push the GPU down into the port and secure it using the screws. This is a good place to secure all the PSU cables and case front panel cables to the motherboard. If you are unsure where to connect your cables, refer to the manufacturer's manual.

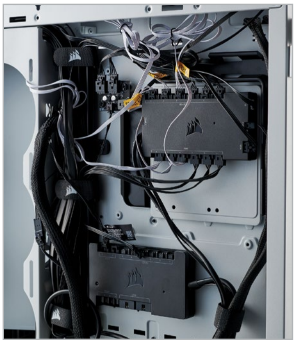
After that, we can start to install the Corsair XD5 reservoir pump. This fits on a bracket that secures onto the bottom of the tank using thumbscrews. Once connected, it sits on another bracket that screws onto the front-facing radiator. This pump needs to be vertical, so we placed it in the middle to give enough clearance above and below for piping. Also, make sure that you have all the input/output pipes accessible. In our build, we had it facing out from the case. The front left hole was for an outlet and either the one next to it or the one on the top right of the reservoir can be used as the inlet. We didn't fully tighten the screws on the first bracket, meaning we could slide it up or down accordingly and then tighten it when in the correct position. In hindsight, this would have been easier to install on the radiator outside the case.

11 FITTING THE FITTINGS

AT THIS STAGE, we can now begin to have some fun with the 14mm fittings and plumbing of this PC. First off, we need to put attachments in all the necessary inlets or outlets. When building a liquid-cooled PC, you need to route out the flow path that goes from the reservoir, through all of your components and radiators, and then back into the reservoir. In essence, it's a simple loop and in each cooling block's manual, it will identify which port is the outlet or inlet. For example, on the GPU block, you can install pipes on the bottom and top, however, they have to be diagonally fitted, as you will see later on in the build. Any unused ports will need plugging up, otherwise, your PC will look like a scene from Titanic, which isn't ideal with all those electronics. As we already have a route planned, we can start mapping it out by installing all of our 14mm standard and 90-degree fittings.



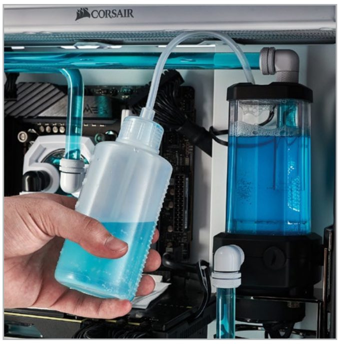
14 CABLING



WE FOLLOWED OUR PLAN and after all the necessary cutting, bending, and fixing were complete, we tightened the fixings and created a loop. This was a time-intensive task, requiring a lot of patience, especially for a first time. In this loop, you need to fit a drain tap at the lowest point, below the reservoir and facing towards the back of the case. It also has a plug, just in case the tap fails. Once this loop was secured, we could start to connect the cabling from the cooling blocks and reservoir. Although the case already comes with a Commander unit, we installed another Commander Pro from Corsair below to accommodate these connections. The case commander unit was full of the six fans we have in this build.

Luckily these cables link up through a daisy chain system. As we only had two ports, we connected the CPU to the Commander Pro and then we linked the GPU and the Reservoir pump together with the daisy link and then installed one of the connectors into the remaining LED port to get all the lighting working. The commander pro connects to a USB 2.0 header on the motherboard too and a SATA connection. We also inserted our DDR5 RAM sticks onto the motherboard at this point. As we only have a two-piece kit, we needed to use the second and fourth DIMM slots on the mobo. These DDR5 sticks are simple to pop into place, they only go one way round, just make sure the connectors are open.

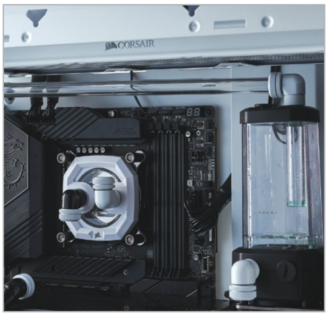
15 TANK PRIMING



WHAT'S A LIQUID-COOLED PC without the liquid? After hooking all of our connections up we could start to fill this machine with coolant. When filling it for the first time, you need to prime the pump. This runs from a secondary PSU which contains a motherboard 24-pin cable with a breaker unit connected to it and also a Molex cable that connects to the bottom of the reservoir. This breaker on the end of the 24-pin tricks the PSU into powering up. It's no issue if you don't have a secondary PSU to spare, you can still use your one, just make sure you only have the Molex and the motherboard cable plugged in with the breaker installed. Once everything was connected, we unscrewed the plug for the fill port and were ready to start filling.

Our coolant was a clear Corsair XL8 with a splash of blue concentrate at a 10/1 ratio. For some protection and to check for any leaks, we filled the case with paper towels around the fitments and crossed our fingers. We poured the coolant into our filling bottle and then gradually started to fill the reservoir tank. With it three-quarters full, we turned the PSU on and started to run the liquid through our system. Before the liquid reaches the bottom of the tank, turn the PSU off and refill. Repeat this process until all the pipes are filled and the tank is nearly filled.

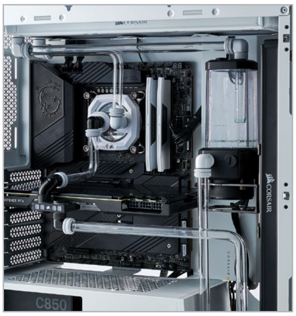
12 THE FIRST PIPE



AS THIS WAS my first liquid-cooled machine, I started off with a straight piece of tubing to get things going. These 14mm hard tubes need to be cut down in length to fit, so to get this measurement right you need to measure from where the fitment starts on each end. With a hacksaw, cut down just over what you have measured out as you can always reduce the length of the pipe. Thankfully, the Corsair kit contains this saw and a vice mount to keep the tubing nice and secure when cutting. Once you have your length cut, you need to use a tube reamer deburring tool to give the tubing a smooth lip around the edge. This can make a slightly uncomfortable screech sound, but don't worry! Using both sides of the tool, twist it on the tube gradually as you don't want to make the tubing too short.

After you're happy with your tube, see if it fits. This can be tricky but just angle your fitments a little wider to make room for the pipe. Then if that's all good, you add the compression fittings. These split into two parts. One part goes into the connection and the other you put on the tube when installing, then slide it up and it clamps the tube into the fitting. It also contains a rubber O-ring to keep things nice and secure. Tighten this on each side and then you should have a secure fitment. Always make sure you tighten everything as much as you can to stop any potential points of failure. Leaks aren't going to be fun for anyone.

13 PIPE BENDING

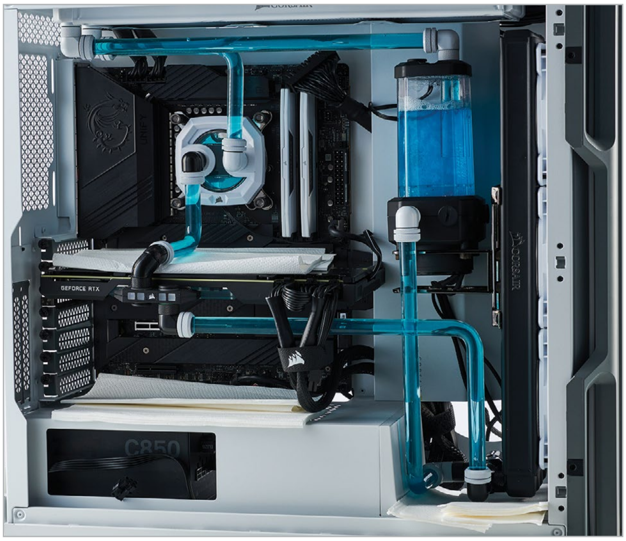


IT MAY LOOK LIKE we've just jumped ahead here, but a lot of liquid cooling is rinse and repeat. You may be wondering about the bends in the build—in theory, these work in the same way as a standard bit of pipe, with the same cutting and deburring. The only difference is the bend, which is made using a heat gun. It's an intimidating-looking tool, but with a little practice, I was able to create a decent 90-degree angle. Using the silicone rod in the kit, mock the pipe up inside the case to figure out the length you need. Again, cut more than this, as you can always trim it down. Lubricate the silicone rod with water and insert it into your cut tube, making sure you can easily pull it out. Have a bowl of cold water nearby for cooling the tube down.

On low heat, hold this tubing above the heat gun and slowly rotate to heat the section on the tube you want to bend. When measuring the tube, score a line roughly where the bend will go and keep the heat focused on this point. Hold the tube about an inch above the heat whilst gradually spinning it. As you do this, you'll start to feel it loosen up, and with a little wiggle, this will start to bend. Heat the inside of the bend you are forming, then bring it to the corner of a table to get a 90-degree angle on the pipe. Blow on it to cool it and then dunk it into the cold water to set the pipe into place. If you're new to tube bending, practice first on a rough cut of tubing.

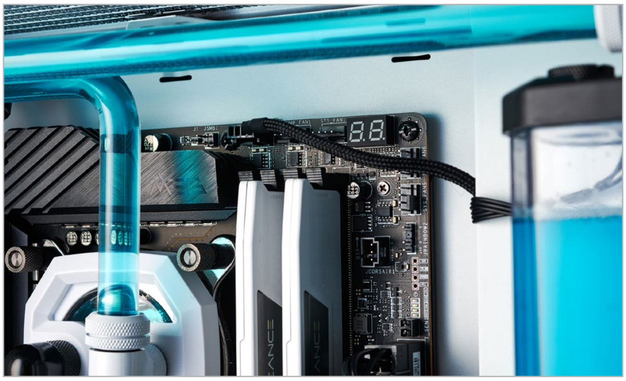
16 LETTING THINGS SETTLE

TRY TO SQUEEZE the coolant in gently through the filling bottle to avoid foaming. Unfortunately, we were a little hasty and got some bubbles but these will naturally go away after running the system for some time. We left the PSU on and secured the plug in the top of the fill port, checking all of our paper towels—not a splash of blue in sight. This is by far the scariest part of the water cooling process, but finding out that there are no leaks certainly lifts a weight off your shoulders. At this point, we could relax.



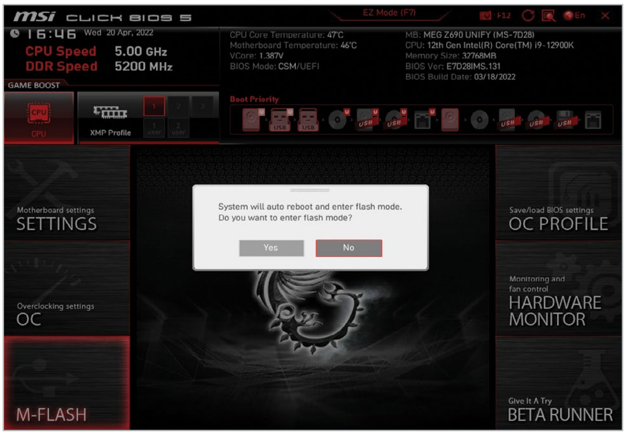
17 THE FINISHING TOUCHES

ONCE THE TANK IS PRIMED, it's time to turn off the secondary PSU and connect the reservoir up to the primary PSU. Make sure all the appropriate cables and connectors are attached and run the pump once more by turning the system on. An important cable to connect is one from the reservoir pump that goes into the CPU fan header to regulate the pump's speed. Also, keep your paper towels in place until you know everything is running smoothly. Once you're satisfied with the build, you can crack on with some cable management and pop the front, top and side panels back onto the case. Lastly, we added the Corsair LC100 case accent lighting to the bottom of the case, which connect up to SATA and are magnetized so stick to the case easily. As we said before, keep the system running and this will hopefully eradicate any unnecessary bubbles in your loop.



18 BIOS UPDATE

SO YOUR PC is now hooked up to a sweet-looking liquid cooling loop, but it still needs a copy of Windows 11 and an updated BIOS. Starting with the latter, we were fortunate enough to boot our system straight into the BIOS. Using another PC, we went to the manufacturer's support page and downloaded the latest BIOS version for our MSI Z690 MEG Unify board onto a blank USB drive. We then headed back into the BIOS by mashing the delete key on a restart and inserting the USB drive with the update file into the PC. We headed into the M-FLASH portion and proceeded to select this update by finding it on the USB drive. After selecting the file, we let the machine do its thing, leaving it to restart after updating to the latest version.

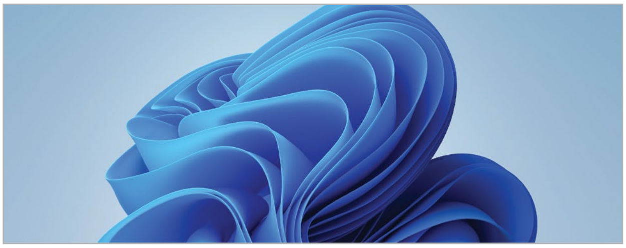

16:46 Wed 20 Apr, 2022
CPU Speed 5.00 GHz
DDR Speed 5200 MHz
CPU Core Temperature: 47°C
Motherboard Temperature: 46°C
VCore: 1.387V
BIOS Mode: CSM/UEFI
MB: MEG Z690 UNIFY (MS-7D28)
CPU: 12th Gen Intel(R) Core(TM) i9-12900K
Memory Size: 32768MB
BIOS Ver: E7D28IMS.131
BIOS Build Date: 03/18/2022

System will auto reboot and enter flash mode.
Do you want to enter flash mode?

19 WINDOWS 11 INSTALL

NOW THAT OUR BIOS is done, we will be installing the latest version of Windows 11 using the media creation tool on Microsoft's website. Install this software using another system then run through the installation wizard. You will need a blank USB drive with at least 8GB of storage, but we just used the same one from earlier and wiped the BIOS update from it. In the installation wizard, select the USB when it asks you where you want to install the media. Then again, sit back and let it do its thing.

Once installed onto the drive, stick it into the new build and boot up the BIOS once more. Here, you need to re-arrange the boot order, making sure the USB drive is first in the priority list then restart, this will then take you to the Windows 11 installation process on your new PC. Follow these steps and you should finally be able to start using your PC. A great tip for new builds is to head to ninite (ninite.com), where you can install a multitude of important applications all at once. Also, make sure to update all the drivers, and download Corsair's iCue software to run the cooling system and lighting efficiently. After that, then you can start to load up Steam on your fancy new liquid-cooled PC.



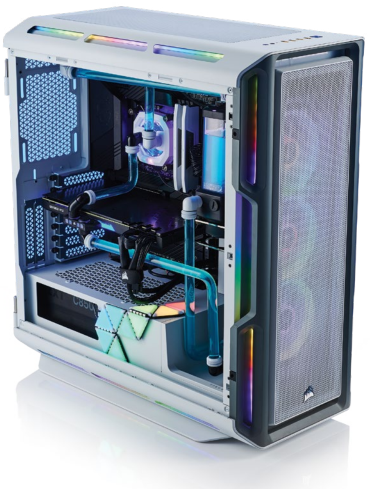
© MSI, MICROSOFT

WATERCOOLING, CHECK

WELL, WE'VE MADE IT. One liquid cooled loop completed and for my first attempt, I have to say it's not half bad! It goes to show that if you've yet to build a custom cooled machine, then fear not, as it's really not as tricky as you may think. Sure, there are a lot more points of potential failure, but if you plan your flow path, you're patient, and meticulously check your fittings, you'll be alright.

As with most builds, there are other issues to consider. When priming our pump, the Molex cable that worked for the secondary PSU didn't work on our primary PSU. We swapped this out for another cable and this fixed the issue but nevertheless spooked us for a moment. Cable management was also a pain in the behind, with less room to work with, daisy-chaining, and two commanders in use, it quickly got messy in the back of the case and took a while to sort.

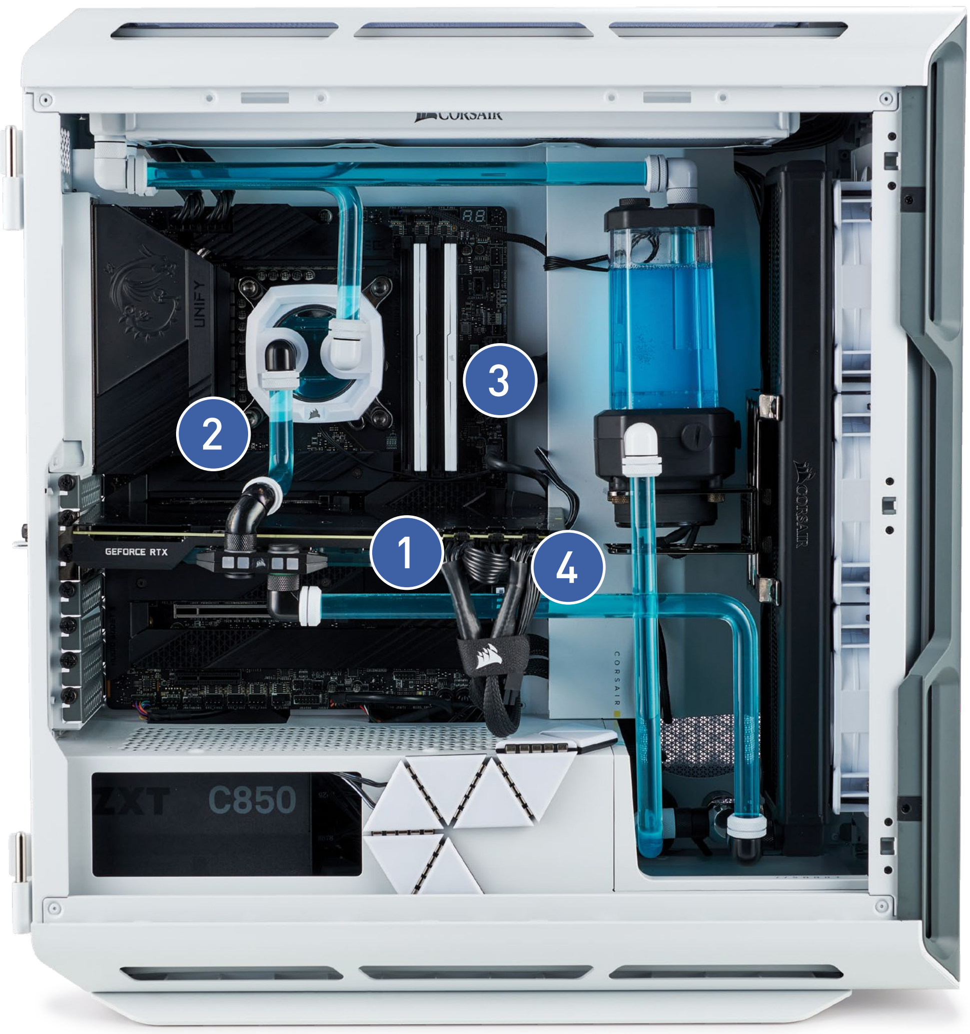
Of course, we ordered the wrong GPU block and we had to take the heatsink off the SSD, ironically using heat. Other than that and some guidance from our former colleague Zak Storey (now at Corsair), who popped back in to show us how to liquid cool, the build went smoothly. It just takes time to practice the tube bending and deburring. It's a lot of trial and error at the start, but you soon pick it up.



So, is it worth liquid cooling? The answer isn't quite a straightforward yes or no. You can think of liquid cooling in a similar vein to the custom car scene. These machines look sweet, and water-cooled builds are certainly attention grabbers and can really transform a setup. Just like show cars, you can customize them to your liking and create something truly unique.

It's not all just for show though, as our benchmarks show, you get a great performing machine on full-whack. However, there are other machines that can achieve these benchmarking results. It's beyond the benchmarking where you notice the difference though, as temperatures are much cooler, which results in a smoother performing rig. This machine is also super quiet as a result of the liquid cooling, with the fans running efficiently when running a high-end game to the point that you don't notice that it's on, especially when wearing a headset.

There is just one big catch, and that's the price. It's fair to say that this is for an enthusiast, as liquid cooling can soon get pricey and if you want to add this to an already expensive arsenal of components, it's going to only add more heft to the bill. Then again, PC building is a hobbyist experience and liquid cooling is the crème de la crème. ⏻



① With the added weight from liquid cooling the GPU, we could have done with a GPU bracket to level it out. This slight sagging on the card is frustrating, to say the least.

② We mixed and matched our 14mm fittings but this build probably would have benefited from choosing just one color.

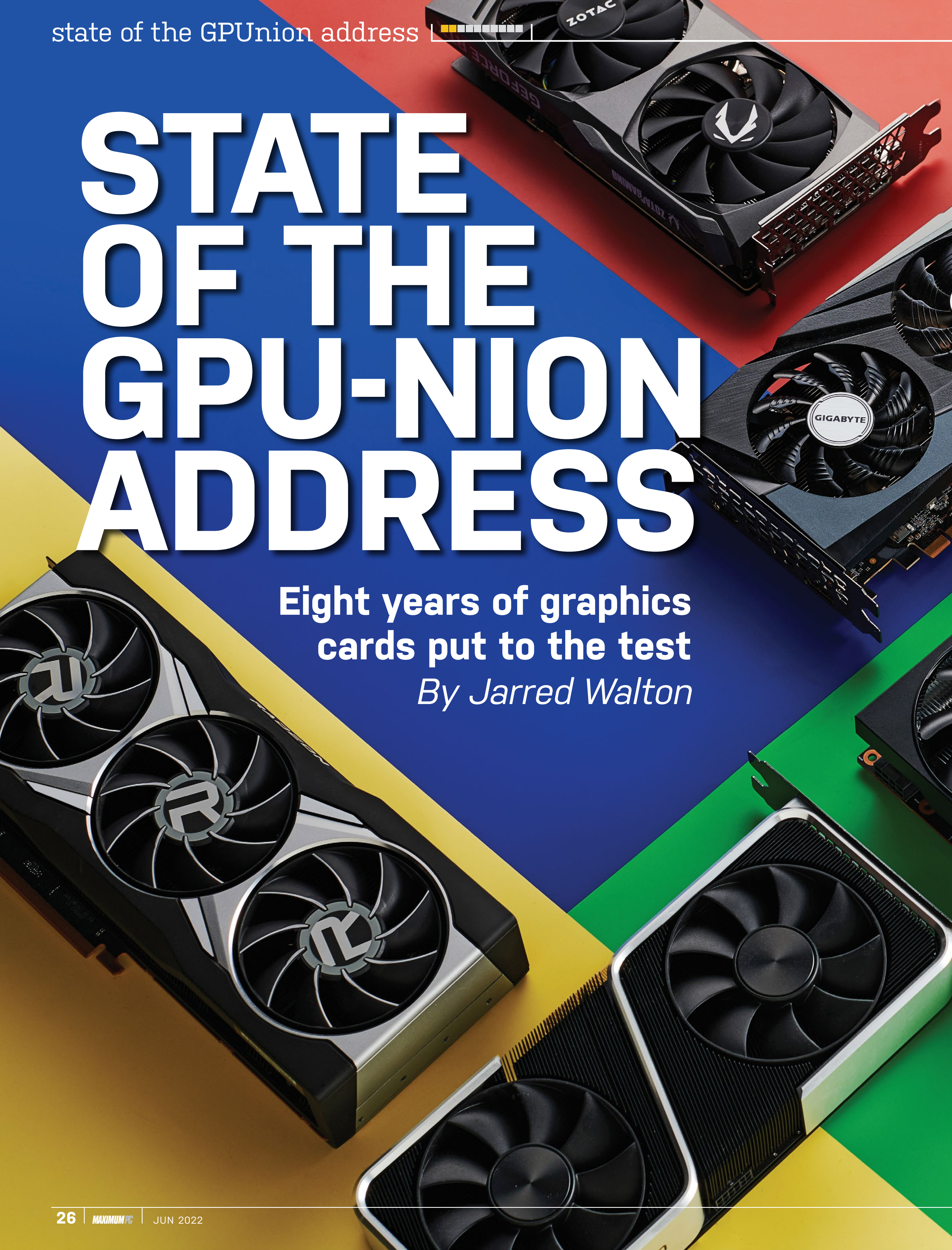
③ We know RGB divides opinions but this is a bold colorful build. We could have gone all-out and opted for Corsair's Dominator DDR5 RGB sticks.

④ Custom white cables would have really pieced this build together nicely and matched the aesthetic of the build.

BENCHMARKS

	ZERO POINT	
CineBench R15 Multi (Index)	4,189	3,859 (-8%)
CrystalDisk Q32T1 Sequential Read (MB/s)	3,344	6,845 (105%)
CrystalDisk Q32T1 Sequential Write (MB/s)	2,911	5,140 (77%)
3DMark: Fire Strike (Index)	37,817	37,890 (0%)
Rise of the Tomb Raider (fps)	78	131 (68%)
Total War: Warhammer II (fps)	98	101 (3%)
Tom Clancy's Ghost Recon: Wildlands (fps)	69	74 (7%)
		0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point conists of an Intel Core i9-12900K, 16GB (2x8GB) Corsair Vengeance DDR5 @5200, an ASUS ROG Strix GeForce RTX 3080 and a 2TB WD_BLACK SN750 M.2 PCIe 3.0 SSD. All game tests are performed at 3840 x 1600 at the highest graphical profile.


ZOTAC
GEFORCE
ZOTAC GAMING
GIGABYTE

STATE OF THE GPU-NION ADDRESS

Eight years of graphics cards put to the test

By Jarred Walton

GIGABYTE
RTX 3080 Ti
GIGABYTE
GIGABYTE EAGLE
RADEON
PowerColor
RTX 3070 Ti

From ultra-budget offerings to extreme Titan cards and everything in between, we've put in hours of benchmarking to bring you a guide to GPU hierarchy.

THE PAST TWO YEARS of pandemic-induced scarcity and supply chain disruption, coupled with cryptocurrency mining mania, have for many dashed hopes of a new graphics card. Nearly 18 months after the launch of AMD's Radeon RX 6000-series and Nvidia's GeForce RTX 30-series GPUs, Steam data shows only 15 percent of gamers use Ampere cards, and under one percent use AMD's RDNA 2 chips.

But plenty of graphics cards are still fast enough to play today's demanding games. To help put things in perspective, we rounded up all the major GPUs from the past six years (plus a few from further back) and put them to the test. Which cards still have staying power and which have fallen by the wayside? Our requirement is that each card needs to work with Windows 11, so join us as we delve through GPUs past.

WELCOME TO THE MODERN ERA

Midway through 2022, Windows 11 is coming up to its first anniversary and it looks as though the pandemic may finally be subsiding. It's also the second anniversary of the current graphics architectures from AMD and Nvidia, RDNA 2 and Ampere, so it's a good time for a look at the state of the GPU industry. But we're not just interested in the latest offerings, we want to see how previous-generation GPUs stack up, so we've rounded up a huge collection of graphics cards and tested every one in a system that's about as modern as it comes.

We're running a Core i9-12900K CPU, cooled by a Corsair H150i Elite Capellix AIO. Our motherboard is an MSI Z690-A Pro WiFi DDR4, a small concession to sanity since DDR5 prices are high and the change in memory doesn't necessarily improve performance. We have 2x 16GB of Corsair DDR4-3600 16-18-18 memory, which has worked flawlessly with the XMP profile enabled, and a large and spacious 2TB M.2 PCIe 4.0 SSD in the form of the Crucial P5 Plus. All of this is powered by a 1200W Cooler Master 80 Plus Gold PSU, which might have seemed overkill until Nvidia rolled out the RTX 3090 Ti.

Using a state-of-the-art CPU and motherboard with many of the graphics cards we've collected won't matter much for performance, but we wanted to show every GPU in the best light possible. The Core i9-12900K reigns as the fastest CPU for gaming purposes, thanks to its high single-threaded performance and clock speeds. We'll still encounter CPU bottlenecks in some games, such as *Microsoft Flight Simulator* when running at 1080p, but we've tried to remove them.

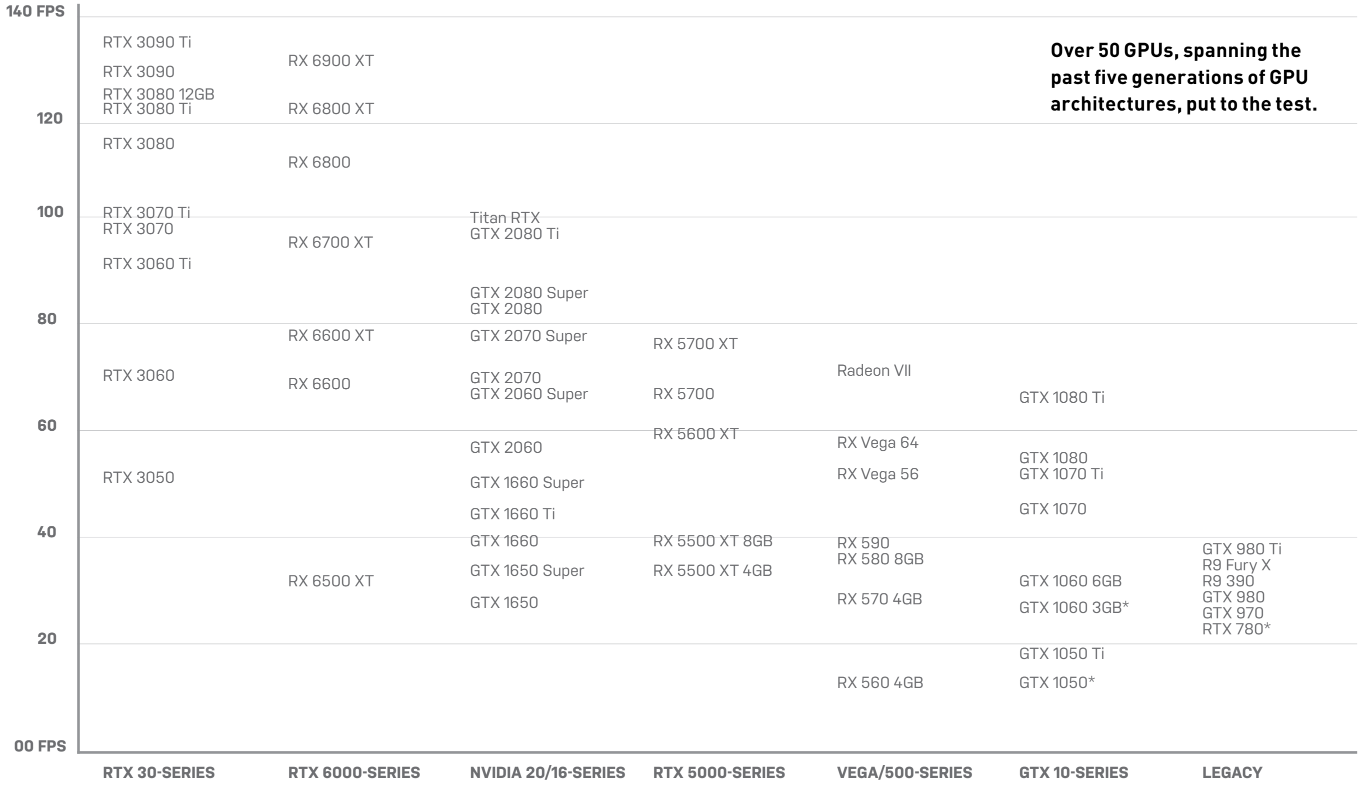
We could have tested at higher resolutions to ensure that the CPU isn't the limiting factor, but that presents a completely different set of problems. Modern GPUs with more than 8GB of VRAM might be able to run maxed out settings and resolutions up to 4K, but older and slower GPUs are another story. Even with limiting our testing to 1080p, running ultra quality settings wasn't possible in at least one game, *Red Dead Redemption 2*, unless the card had at least 4GB. That sets the stage for the results, but first, let's talk about the games we're testing.

We've benchmarked eight games in our standard test suite: *Borderlands 3*, *Far Cry 6*, *Flight Simulator*, *Forza Horizon 5*, *Horizon Zero Dawn*, *Red Dead Redemption 2*, *Total War: Warhammer 3*, and *Watch Dogs Legion*. In addition to those, we also tested six more games on cards that have hardware ray tracing support: *Bright Memory Infinite*, *Control Ultimate Edition*, *Cyberpunk 2077*, *Fortnite*, *Metro Exodus Enhanced Edition*, and *Minecraft*. All six games use multiple ray tracing effects, which we feel is important to highlight the image fidelity and performance requirements of RT hardware.

Every GPU was tested multiple times at each setting and scores were selected after eliminating any outliers, to provide the best set of comparable results. We also tested at higher resolutions, where it makes sense. The total amount of data gathered includes thousands of benchmark runs, conducted over several months, using the most up-to-date drivers available at the time of testing.

Our choice of hardware wasn't without its problems, particularly on some of the older graphics cards.

GPU STATE OF PLAY
PERFORMANCE AT 1080P ULTRA (FPS)



Over 50 GPUs, spanning the past five generations of GPU architectures, put to the test.

* GPU could not run all of the test due to insufficient VRAM

GPUs aren't just for games, with supercomputers using them for weather simulations, deep learning AI routines, and more.

Enabling resizable BAR support in the motherboard BIOS as an example caused the Radeon VII to refuse to even POST (Power On Self-Test), even though it doesn't even have the hardware and software support to benefit from the feature. Disabling the settings (with a different GPU installed) fixed that, which is a configuration probably few if any people will ever try. Overall, though, we were pleased to see that we encountered relatively few quirks.

PLEASE CHECK YOUR DRIVERS

Driver support represents a potential hiccup when trying to use an older graphics card on Windows 11, or even with Windows 10. AMD still has current driver support for everything back to its RX 400-series GPUs with its latest drivers. That covers graphics cards from Team Red dating back to 2016. What about the older stuff, like the 300-series and 200-series parts from 2014 and 2013, or even the newer R9 Fury family from 2015? Windows 11 will download drivers for that hardware, but the last driver update from AMD came in May 2021, so you may encounter some incompatibilities with more recent game releases.

Nvidia's driver support extends further, with the current release supporting everything back to the GTX 900-series. That means any GPU from Team Green made in the past eight years should still have support, and the GTX 700- and 600-series cards got a final driver release last September—and a security patch was released in January for those GPUs. Conceivably, you could run a graphics card from a decade ago on a modern PC and it will still work...most of the time.

Of the games we tested, a few complained about outdated drivers on some of the legacy GPUs. Despite the complaining, most of the games still ran just fine, but *Forza Horizon 5* failed to run using the default drivers that Windows 11 installed. The solution was to download the latest Windows 10 drivers, and then the game ran fine.

Note that while there are still plenty of people gaming on older CPUs, graphics

INTEL ARC PREPS FOR A FLOOD

The big two GPU names are about to get some much-needed competition from Intel's Arc, or at least in theory. Arc, formerly DG2, aka Xe-HPG, has seen quite a few delays. We originally thought it would launch by the end of 2021, but now it's looking like a mid-2022 launch for the desktop parts. It could be too little, too late for gamers, though the media aspects of the chips remain promising.

Intel recently revealed the initial lineup for laptop Arc A-series models, which will inevitably be paired with Intel CPUs. Given Intel dominates the laptop landscape in sales, it's probably a smart business move, but it doesn't give us a lot of hope for high performance.

Intel compared its lower-tier A370M part against its own integrated Iris Xe Graphics, from a Core i7-1280P. That's a 28W mobile chip with 96 Execution Units (now called XVE, for "Xe Vector Engine"), going up against a 35–50W A370M with 96 of the new XVEs. Performance was over 50 percent faster, but our previous testing suggests that will be quite a bit slower than even a GTX 1050.

The highest tier Arc chip, A770M, will come with 512 XVEs and faster memory. That's 4096 shader cores and a potential compute performance of 13.5 TFLOPS FP32. Theoretical performance isn't the same as real-world performance, but even in a best-case scenario, that puts the A770M on par with Nvidia's mobile RTX 3070.

Intel isn't just talking about graphics performance, however. Arc also includes XMX units (Xe Matrix eXtensions), which are basically Intel's equivalent of Nvidia's Tensor cores. Each XMX can perform 128 FP16 operations per clock, so the A770M has a peak throughput of 108 TFLOPS for deep learning and AI acceleration. Intel will be using the XMX engines for its XeSS (Xe Super Sampling) upscaling algorithm, which sounds a lot like DLSS. XeSS will also be able to run on DP4a (INT4) hardware, for non-Arc GPUs including AMD RDNA and newer and Nvidia Pascal and newer architectures.

Intel will have two main Arc chips, the ACM-G10 and the smaller ACM-G11.
00071
TL7
00329
intel
ARC
intel
ARC

Finally, Intel will include up to 32 ray tracing units (RTU) in its top Arc GPU. Unless Intel's RTUs are far more potent than those of Nvidia or even AMD, we don't expect much from Team Blue when it comes to its first generation of ray tracing hardware. The lowest tier Arc A350M for example has just six RTUs clocked at 1150MHz, with 4GB VRAM on a 64-bit interface. Based on those specs, it might make even the RX 6500 XT look fast.

We'll find out just how the Arc chips stack up in the real world in the coming months, but we have a sinking feeling.

© INTEL, GETTY IMAGES/IMAGINIMA

As with cars, putting the wrong driver at the wheel can be a recipe for disaster with graphics cards.

© GETTY IMAGES/RICHVINTAGE

cards tend to not age quite so well. Even if there aren't driver issues, modern games push the hardware in new and demanding ways, and sometimes older GPUs simply fall flat on their faces. But if you're just trying to play *Fortnite* or other less demanding games and you're willing to drop the settings and resolution, even relatively ancient hardware can still get the job done—assuming you didn't kill the GPU with crypto mining, naturally.

GAMING PERFORMANCE OVER TIME

You won't be shocked to see a clear trend of improving performance through the generations of hardware. Today's RTX 3090 Ti basically doubles the performance of the GTX 1080 Ti, and the same goes for the RX 6900 XT and the two-generation old RX Vega 64. Go back another generation to the R9 Fury X and the GTX 980 Ti and the gap becomes even larger, with modern high-end cards like the RTX 3080 and RX 6800 XT more than tripling the performance of the fastest cards in 2015, the GTX 980 Ti, and R9 Fury X.

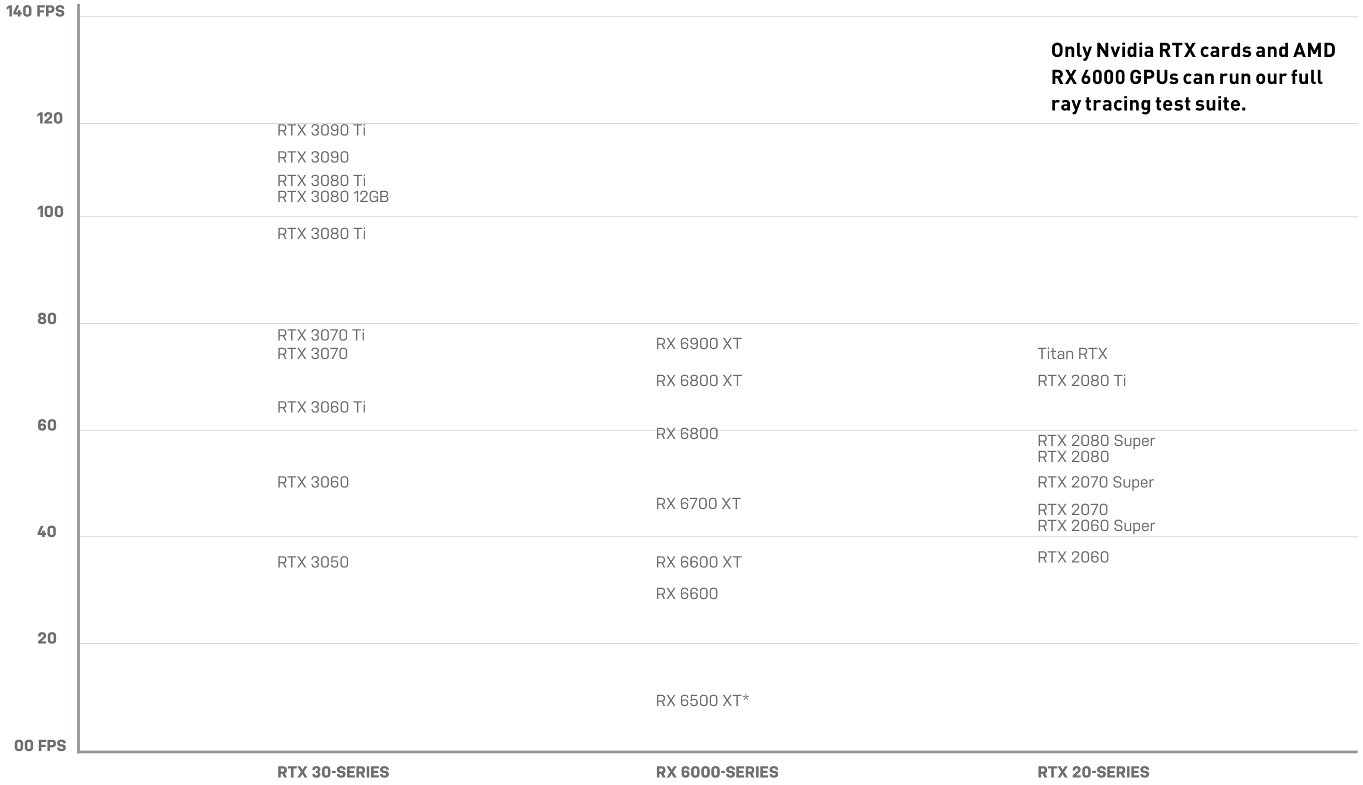
As impressive as that is, let's keep things in perspective. The fastest GPUs in 2015 packed 8 billion transistors into a 601mm^2 die size, the GM200 used in the GTX 980 Ti. Today's GA102 that powers the RTX 3090 Ti sports a whopping 28.3 billion transistors—3.5 times as many—in a chip measuring 628mm^2. Clock speeds have improved from 1.2GHz in 2015 to nearly 2GHz for Nvidia on the RTX 30-series, while AMD has boosted clocks from over 1GHz on the R9 Fury X to over 2.5GHz on the fastest RX 6000-series GPUs.

In other words, looking at transistor counts and clock speeds, GPUs haven't even managed to achieve linear scaling. We have larger chips, with lots more transistors, running substantially higher clocks, but performance has started to taper off. On the other hand, today's chips do a lot more than those of six years ago, with features like ray tracing and DLSS.

Another way of looking at it is to focus on a specific level of GPU, like Nvidia's 980, 1080, 2080, and 3080. Here's where the end of Moore's Law and Dennard scaling become more obvious. The 1080 boosts performance by 84 percent over the 980, the 2080 is 55 percent faster than

GPU STATE OF PLAY

RAY TRACING PERFORMANCE AT 1080P MEDIUM (FPS)

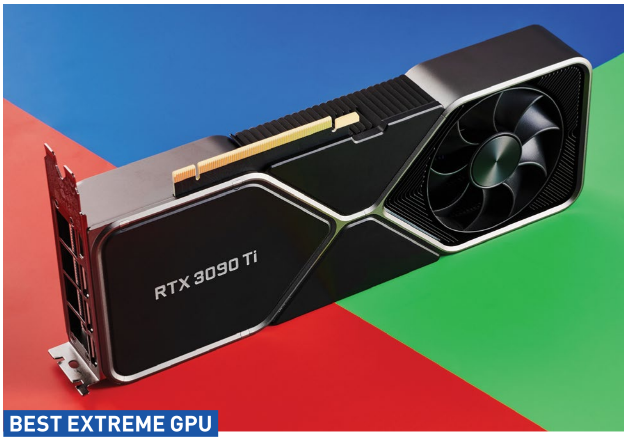


Only Nvidia RTX cards and AMD RX 6000 GPUs can run our full ray tracing test suite.

* GPU could not run all of the test due to insufficient VRAM

THE BEST EXTREME, HIGH-END, MIDRANGE, AND BUDGET GPUs

Going all out on pure performance might sound great, but most people need to strike a balance between framerate and cost. Putting everything together, we've picked the four best options for various budgets, keeping in mind that graphics card prices still aren't completely back to normal. If you need something right now, here's what we recommend, though waiting for the next-generation cards to arrive later this year should provide more bang for your buck.



BEST EXTREME GPU

GEFORCE RTX 3090 TI ($1,999)
When your only goal is to get the fastest graphics card possible, the choice is simple. Nvidia's latest and greatest might not be particularly efficient, and your wallet might go on strike, but there's no question this represents the current pinnacle of GPU performance. The law of diminishing returns is in full effect, so paying about three times as much as our high-end pick will only get you around 35 percent more performance. Thanks to Nvidia's DLSS, however, you can generally break 60 fps at 4K even with demanding ray tracing games.

BEST HIGH-END GPU

RADEON RX 6800 XT ($649)
One and a half years after launch, AMD's Radeon RX 6800 XT is a compelling option, particularly if you're not convinced of the need for maxed-out ray-tracing settings—if that is something you care about, the RTX 3080 is a close second for this category. You'll get 16GB of VRAM, which should be plenty for the next few years, and AMD's prices make this a better value than other options. Street prices are close to $850 at the time of writing, but prices have been dropping by 10 to 15 percent per month this year. Hopefully, as you read this, cards will be under $700.

BEST MIDRANGE GPU

GEFORCE RTX 3060 TI ($399)
The RTX 3060 Ti almost seemed too good to be true. It was faster than the previous generation RTX 2080 Super and only marginally slower than the 2080 Ti, and prices were supposed to start at just $400. Of course, thanks to the usual culprits, including global shortages and crypto-miners, the RTX 3060 Ti ended up selling for $1,000 or more during most of last year, however, prices are finally coming down—and fairly rapidly too. If you want to save even more money, check out the non-Ti 3060 with 12GB VRAM. This was an extremely close runner-up in our tests and was available for under $500, at the time of writing.

GEFORCE RTX
GIGABYTE
EAGLE
GIGABYTE
GIGABYTE

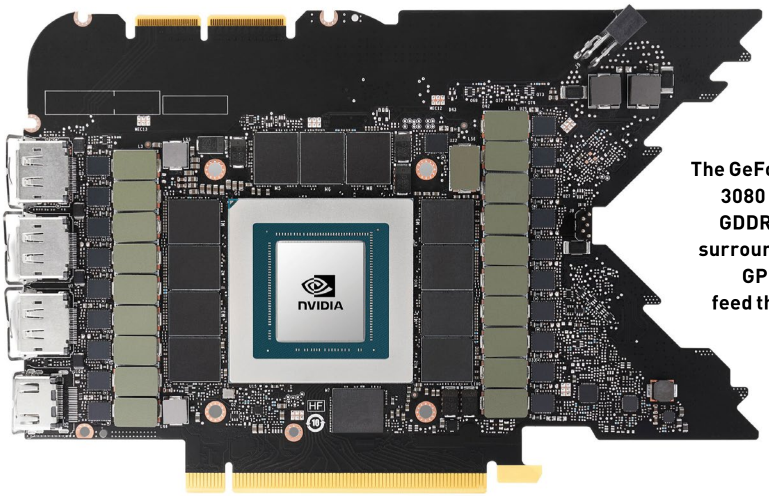
BEST BUDGET GPU

GEFORCE RTX 3050 ($249)
"Budget" means different things to different people, but we prefer to pay a bit more for substantially improved features and performance. The RTX 3050 rates as the slowest ray tracing card that's still worthy of consideration, with a very competitive price. The GTX 1660 Super only costs slightly less, but it's slower and can't run ray tracing games worth a spit, plus the RTX 3050 still supports DLSS and can get a healthy performance boost in games that support the technology. If you can't stomach the price, you'll probably want to stick with whatever you currently have and save up money rather than pinching pennies.

the 1080, but the 3080 is only 40 percent faster than the 2080. AMD's GPUs tell a similar story, the shape of things to come.

The other end of the performance spectrum tells a mixed story. The RTX 3050 more than triples the performance of the GTX 1050, but we're looking at a budget card from five years back that launched with a $110 price tag going up against a midrange card that costs more than twice as much—there's no actual 'budget' RTX 30-series offering so far.

AMD's budget GPUs show an even more perplexing story, with the RX 5500 XT doubling the performance of the RX 560, but then the latest RX 6500 XT takes a step backward from there—and both of the newer generation cards carry substantially higher prices than the $100 launch price on the RX 560 4GB. Of course, you don't need to run maxed-out settings (see sidebar on ultra quality), but if you're already running medium settings, you'll be in need of an upgrade sooner than later.



The GeForce RTX 3080 Ti has 12 GDDR6X chips surrounding the GPU to help feed the beast.

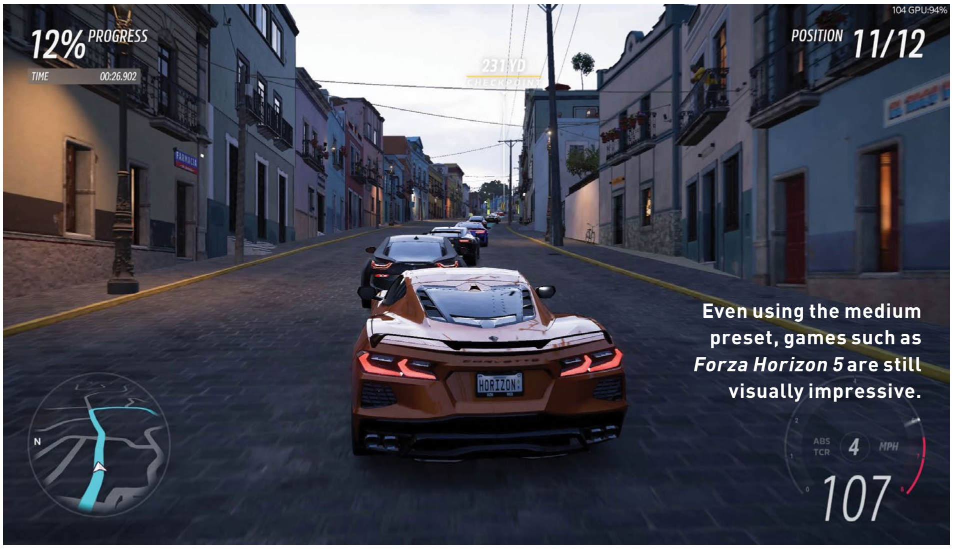
THE NEED FOR MORE VRAM

One noteworthy change that we've seen repeatedly through the years is the need for more VRAM. There was a time when people were debating between 1GB and 512MB graphics cards and, before that, we argued about 128MB vs. 64MB. Today, we've reached the point where 4GB is barely sufficient to run all of our benchmarks and there are several games in our test suite that will warn about the lack of graphics card memory—*Far Cry 6*, *Forza Horizon 5*, and *Watch Dogs Legion* can even suffer from degraded performance with 8GB of VRAM! Game developers clearly want more VRAM for their purposes, and with high-resolution textures, more detailed models, and technologies like ray tracing, 8GB represents the bare minimum of what we want to see on any midrange or higher GPU. If you want a great example of the difference more VRAM can make, just look at the R9 390 and GTX 980.

YOU DON'T NEED ULTRA QUALITY

Depending on the game, the difference in visual fidelity between medium settings and ultra settings may not be worth the performance penalty. Those running extreme GPUs, like the RTX 3090 or RX 6900 XT, can safely set phasers to vaporize and carry on. But if your GPU is long in the tooth, dropping the settings a notch or two can do wonders for performance—particularly if you're using a graphics card that doesn't have at least 4GB VRAM, and some recent games even want 8GB just for 1080p ultra.

Take the GTX 1050, which sits at the bottom of the rankings in terms of 1080p ultra-performance and delivered just 15fps on average. Dropping to 1080p medium doubled its performance, and while a few games still struggled—*Warhammer 3* and *Flight Simulator* still failed to break 30fps—most games are at least playable.



Even using the medium preset, games such as *Forza Horizon 5* are still visually impressive.

What can you expect from medium-quality visuals compared to ultra quality? There's a bit less of all the finer details, like shadows and reflections, but in some games, the ultra settings feel like a placebo. The Xbox One and PlayStation 4 essentially run at settings comparable to medium quality in most games, and millions of console users still enjoy playing games on those systems. 30fps at 1080p medium might not be much to brag about, but if the only other option is not to play, don't be afraid to give it a shot.

Similarly, if you aren't rocking top-shelf hardware, you'll be far better off running at 1080p than at 1440p or 4K. Even if you have a 4K monitor, playing games at 1080p is a reasonable option, and upscaling technologies like AMD's Radeon Super Resolution (RSR) and Nvidia Image Scaling (NIS) can still provide a pleasing result.

© XBOX GAME STUDIOS, NVIDIA

Back in 2015, when the newly released R9 390 was running the games of that era, there was no question about which was faster—the Nvidia card was consistently about 10 percent faster. Fast forward to today and the R9 390 with its 8GB now leads the GTX 980 by 3 percent at 1080p, and the lead grows at 1440p (not that either card is really playable at 1440p ultra these days). Similarly, the Fury X used to be nearly 30 percent faster than the 390, but now that lead has shrunk to 19 percent, and the two cards are virtually tied for performance in *Far Cry 6* and *Forza Horizon 5*.

Cards with 6GB of memory strike an interesting middle ground. There are still times when it's not quite sufficient for ultra settings, but the GTX 1060 6GB as an example outpaces the GTX 980 by 12 percent in our modern suite of games, where it was a few percent slower than its predecessor back in 2016.

Going forward, we've mostly reached the end of the road for 4GB cards. They still have a place in the budget sector, but the RX 6500 XT would have benefited greatly from having more memory and a wider memory interface. 8GB cards are still generally safe, but there are certainly games where you'll want to drop a few settings (like texture resolution) to avoid memory thrashing—where there's too much data needed in the GPU's VRAM, and it ends up having to pull in data over the much slower PCIe bus. At the same time, going beyond 12GB definitely isn't needed in our current test suite, and while it's inevitable we'll eventually see consumer graphics cards with 32GB or more memory, that's many years away from becoming close to mainstream.

FOUR YEARS OF RAY TRACING

Who doesn't love eye candy? With its GeForce RTX graphics card launch in 2018, Nvidia ushered in the era of real-time ray tracing for games. Since then, the rate of adoption has been more of a slow burn. We all know what ray tracing—or the more advanced path tracing—can do for movies, but getting similar results at real-time framerates remains difficult.

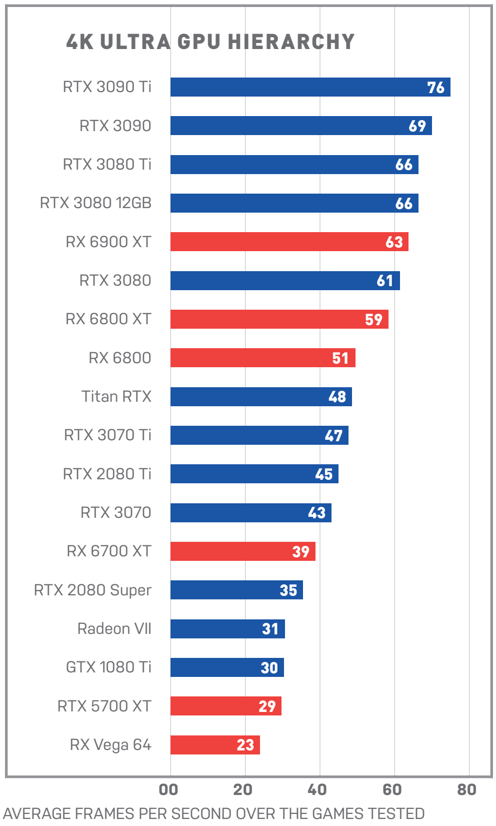
We've selected the best showcases for ray tracing in games, with multiple RT effects including shadows, global illumination, reflections, ambient occlusion, and caustics. Ironically,

MAXED OUT AT 4K

It doesn't make sense to test most graphics cards at 4K and ultra quality, as the vast majority of older GPUs will gurgle and die while trying to choke down such a workload. However, for those that have the requisite display and want to know what sort of graphics card they should use, we tested a subset of the fastest 18 GPUs from the past five years.

The RTX 3090 Ti naturally claimed top honors, with an even greater lead over the competition than at lower resolutions—CPU bottlenecks are no longer a factor at 4K. It's 10 percent faster than the RTX 3090, and 20 percent faster than AMD's RX 6900 XT.

More importantly, the previous generation's top GPUs came in well below the 60fps mark, with 48fps on the Titan RTX, 45fps for the RTX 2080 Ti, and 39fps from the RX 5700 XT. Going back one more generation, the Radeon VII and GTX 1080 Ti barely managed a 30fps average, with multiple games falling well below that mark.



AMD AND NVIDIA GPU FEATURES

The latest generation GPUs from AMD and Nvidia both support ray tracing and the full DirectX 12 Ultimate feature set, which defines the baseline of what we expect to see going forward. Nvidia still has some extra hardware in its tensor cores, which power technologies like DLSS (Deep Learning Super Sampling) and Nvidia Broadcast, and those are both useful additions.

AMD offers something of an alternative to DLSS with its FSR technology, which is due for a major update in the not-too-distant future. FSR 2.0 will move to a temporal upscaling solution, but it will still work on a wide range of GPUs, including those from the competition.

Intel meanwhile has XeSS (Xe Super Sampling), which sounds an awful lot like DLSS, only done on Intel hardware. But having a software solution such as DLSS or FSR isn't the same as getting it adopted by game developers, and DLSS easily wins in that arena.

Stepping back to earlier generation GPUs can mean giving up features, and in some cases, certain games may refuse to run at all. Of our test suite, *Far Cry 6* was the only game that didn't want to run on one of our legacy GPUs. The GTX 780 lacks the appropriate DirectX feature level, and the game simply failed to run despite our best attempts. Of course, there are also games such as *Metro Exodus Enhanced Edition* that require ray tracing hardware, so you'll need at least an AMD RX 6000-series or an Nvidia RTX card to run it.

Other features that ultimately deliver more performance, like AMD's Infinity Cache, aren't particularly important to the end-user, as speed is often the goal. However, video codec support can be important, especially if you're thinking of using a card in a home theater setup.

Nvidia currently delivers better overall video encoding and decoding hardware, though Intel's upcoming Arc GPUs will be the first with hardware AV1 encoding and decoding support. Nvidia's Ampere and Turing GPUs support hardware HEVC and AVC encoding and decoding, except for the GTX 1650.

AMD's 6000- and 5000-series GPUs also support hardware HEVC and AVC encoding and decoding, except for the RX 6500 XT.

perhaps the best example of what full RT can do comes in the form of *Minecraft*, which normally runs on everything including your old and moldy potato PC sitting in the corner.

Nvidia says the enhanced version of the game implements full path tracing, which isn't entirely correct, but it does radically alter the visuals with a detailed lighting model that handles reflections, indirect lighting, and more. It also destroys performance, often taking a game that can easily render at hundreds of frames per second without ray tracing down into the sub-60 and even sub-30 range. And that's all for the same base blocky world—getting all of those effects rendering in a more complex game at acceptable framerates simply isn't possible on today's hardware.

Not surprisingly, since Nvidia was the first out of the gate with ray tracing hardware by over two years, the various RTX GPUs rank at the top of our ray tracing charts. We're using our "medium" ray tracing settings for the overall standings, which puts Nvidia's top RTX 3090 Ti 50 percent ahead of AMD's top RX 6900 XT. Meanwhile, the slowest ray tracing card so far, AMD's RX 6500 XT, failed to run one of the games (*Control* wants at least 6GB VRAM or you can't even try to enable ray tracing), and couldn't even break 20fps in the remaining games, with *Cyberpunk 2077* and *Bright Memory Infinite* both well into the single digits. We suspect Intel's lowest-tier Arc offerings might be slower than the 6500 XT (see Intel Arc sidebar).

Cranking the settings to maximum proves too much for many of the GPUs, but Nvidia's lead grows to 66 percent at 1080p ultra and 75 percent at 1440p "ultra"—at which point, even the RTX 3090 Ti just barely clears 60fps average across our six-game suite, with half of the games falling below 50 fps. At 4K ultra, the only way to achieve playable performance is with some form of upscaling like DLSS; native 4K averaged just 29fps across our suite on the 3090 Ti, and half the games were in the low 20s.

AMD's entry into the ray-tracing space more or less lines up with Nvidia's first-generation RTX cards. The RX 6900 XT delivers nearly identical performance to the Titan RTX, and the RX 6600 comes in slightly behind the RTX 2060. Nvidia didn't even try for budget RT hardware the first time round, and poor Navi 24 shows why. Meanwhile, Ampere's second-generation RT hardware is about 75 percent faster than the Turing RT cores, though the RTX 3050 still ends up being slower than the RTX 2060.

WHAT ABOUT LAPTOP GPUs?

Many use laptops for gaming and computing, but going mobile means giving up some performance.

All our testing has focused on desktop graphics cards. It allows us to test the various GPUs while keeping all other hardware constant, but there are also mobile variants of most graphics cards. As you can guess, packing something like a 450W RTX 3090 Ti into a laptop just isn't going to happen, not without drastically cutting the power use. That results in the latest mobile GPUs from Nvidia and AMD generally being at least one step down in performance from their desktop counterparts.

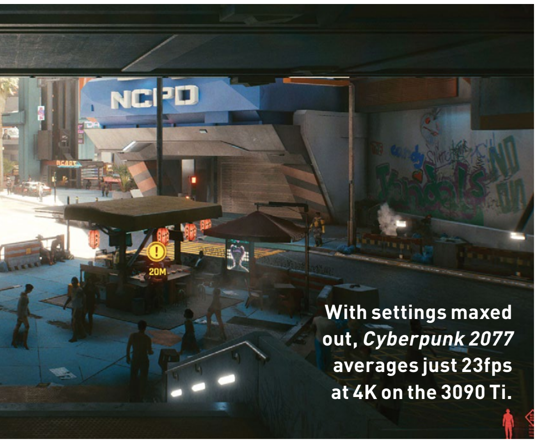
Take the mobile RTX 3080, for example. It uses the GA104 chip, whereas the desktop 3080 uses GA102. It also has 8GB of memory on a 256-bit bus instead of 10GB on a 320-bit interface and comes with 48 SMs and 6144 CUDA cores compared to 68 SMs and 8704 CUDA cores. It typically runs at lower clocks as well. All those cuts are done to keep power consumption under control, and the resulting GPU can be configured to run at 80–150W, depending on the specific laptop and configuration, compared to the base 320W of the desktop 3080.

It's a similar story for AMD. The RX 6800M uses the smaller Navi 22 and has 40 CUs and 2560 shader cores, with 12GB of VRAM and TGP (Total Graphics Power) starting at 145W. The desktop RX 6800 uses Navi 21 with 60 CUs, 3840 shaders, 16GB of memory, and a 250W TGP. The specifics of the various graphics chips over the years may vary, but the net result is the same: lower performance.

The 150W mobile RTX 3080, for example, comes close to the level of a desktop RTX 3070, while the lower limit 80W configuration will often fall behind the desktop RTX 3060 Ti. AMD's RX 6800M likewise falls behind the desktop RX 6700 XT.

The benefit, naturally, is that you don't fry your nether regions when gaming on the go, though battery life still tends to be far less than two hours for anything that really uses the GPU—no, a text-based *Zork* reimagining doesn't count.

© CD PROJEKT


With settings maxed out, *Cyberpunk 2077* averages just 23fps at 4K on the 3090 Ti.

RAY TRACING, ROUND THREE

We need significantly faster hardware if we want to plow through all these ray tracing effects while maintaining high framerates. Thankfully, that should be coming soon with Nvidia's Ada and AMD's RDNA 3 GPUs—and also the Intel Arc wildcard (see sidebar), but we're skeptical it will be competitive. They will probably be the RTX 40-series and RX 7000-series, respectively, but whatever the names, we expect both companies to cram in even more transistors. That's thanks to a switch to TSMC's 5nm process nodes—maybe even "4nm" 4N, though the process names are more marketing these days.

For Nvidia, this will be the third architecture with ray tracing support. Ampere added a second ray/triangle intersection pipeline to its RT core, along with some extra hardware to help with more complex ray-tracing calculations like motion blur. Ada will also be the fourth generation of Tensor cores, and we know from the datacenter Hopper H100 (see MPC203 Tech Talk) that Nvidia can create large GPUs with a ton of compute. We don't think the consumer-oriented Ada chips will be quite as extreme as Hopper, but Nvidia could potentially double RT and Tensor core performance yet again. Alternatively, it might put in more RT hardware and focus less on further boosts to deep learning and AI performance.

There was an Nvidia hack this year that leaked some details about the upcoming Ada GPUs. The biggest chip, AD102, has up to 144 SMs—71 percent more than the Ampere GA102. Even if Nvidia keeps the same relative performance per GPU core and SM, stuffing in that many SMs should provide a huge boost to performance, regardless of workload. The second tier AD103 chip has the same 84 SM maximum as GA102, but it should be smaller and presumably less expensive to produce, which could lead to some compelling high-end offerings. Take this with a pinch of salt, but we're looking forward to Ada.

AMD hasn't been hacked by LAPSU$, so we don't know as much about the upcoming RDNA 3 architecture. The data center Aldebaran chips powering the MI250X are massive and have matrix cores similar to Nvidia's Tensor hardware, but so far, AMD has been hesitant to embrace machine learning hardware on consumer products. If AMD skips the matrix hardware on RDNA 3, it could potentially cram in more CUs (compute units, similar to Nvidia's SMs). Or it might decide to add matrix cores and look at supporting Intel's XeSS algorithm—stranger things have happened.

WHEN TO UPGRADE

If your old PC looks like this, you might need more than just a new graphics card.

It's easy to get carried away looking at the top-performing cards and thinking it's time for an upgrade. Resist the temptation, at least until the games and applications you're using warrant the expense. Even then, make sure that your 'upgrade' actually represents a true leveling up of performance.

The oft-quoted rule of thumb is that a previous generation GPU represents one step down in performance, but that's not entirely accurate. For Nvidia, the RTX 2080 lands midway between the 3060 and 3060 Ti, the GTX 1080 performs about on par with the RTX 2060, and the GTX 980 lines up with the GTX 1060. That's two steps down, but if you look at the –70 cards, it's maybe one to one and a half steps down, and among the –60 series chips it's sometimes less than a single step, albeit muddied by the Turing GTX 16-series GPUs. AMD has swapped through various naming paradigms so making comparisons is a bit trickier, but the RX 5700 XT matches up with the RX 6600 XT, Vega 64 takes on the 5600 XT, and Fury X matches up with the RX 580.

If you're sitting on a GTX 1060, which still rates as the most popular GPU according to Steam's hardware survey, it's probably worth thinking about upgrading. Our advice is to try and get a graphics card that's at least double the performance of your current GPU if you want to feel a big improvement. The RTX 3060 gets you that, as does the RX 6600, but if you can splurge on an RTX 3070 or RX 6700 XT you get triple the performance.

The other thing to consider is when new GPU architectures and hardware will launch. Upgrading right before the new stuff comes out is usually the worst approach while being an early adopter can mean paying higher prices. Then again, anyone who paid scalper prices of $1,100 for an RTX 3080 after that card launched probably felt good about the decision when prices shot up to over $2,000 four months later. Let's hope that never happens again.

© GETTYIMAGES/TASCHA RASSADORNYINDEE / EYEEM

magazinesdirect.com

Over 100 brands to choose from

GIFT IDEA! Gifts that keep on giving

3 GREAT REASONS TO SHOP WITH US

- From tech and gaming titles to fashion and celebrity magazines there's something for everyone.
- Immerse yourself in our specialist one-off publications about your favorite hobby or interest.
- Exclusive Offer - Enter code **MDMAG15** at checkout to get 15% Off Guides and Specials.

VISIT OUR ONLINE STORE AT
www.magazinesdirect.com

✓ Convenient home delivery ✓ Save on shop price ✓ Never miss an issue ✓ 1.4m subscriptions sold

SUBSCRIBE & SAVE 76%

PLUS GET A FREE COPY OF

BOOK OF AMAZING TECHNOLOGY

NVIDIA RTX 3090Ti
Team Green's fastest GPU, but is it worth buying? PG. 74
MONITOR MEGATEST
OLED, Mini LED, 8K. New screen tech compared PG. 48
YOUR NEXT LAPTOP
3 portable PCs from Lenovo & Acer reviewed PG. 80
MAXIMUMPC
MINIMUM BS • JUNE 2022 • www.maximumpc.com
WATERCOOLING MADE EASY
Don't liquid cool until you've read our guide!
Screeching speed with no noise
Overclock while staying cool
Beautiful lighting and tubing
EVERY GPU RANKED!
2022 graphics processors compared and graded PG. 26
NEW
AMAZING TECHNOLOGY
EVERYTHING YOU NEED TO KNOW ABOUT THE WORLD'S BEST TECH
UNDERWATER HOTELS
Explore the hotel that can dive below the sea
HI-TECH TRAVEL MACHINES
Your holidays will never be the same
FROM THE MAKERS OF HOW IT WORKS
SMART HOME GADGETS
Discover the tech that will change the way we live at home
NEXT-GEN RACE CARS
The innovations changing the future of motorsport
Digital Edition

~~$136.86~~*

$31.95

GREAT REASONS TO SUBSCRIBE

Save money ● Never miss an issue ● Get every issue delivered to your door

To order go to **www.magazinesdirect.com/mpc/B2FMAG**

or call **1-844-779-2822** and mention code **B2FMAG**

TERMS AND CONDITIONS Savings based off the US newsstand cover price of $9.99 per issue for 13 issues, and the retail price of Book of Amazing Technology digital edition of $6.99 .Offer only valid on 1 or 2 year print or print + digital subscriptions. Book of Amazing Technology will be emailed 3-5 days after payment is processed. Visit us at magazinesdirect.com or call 1-844-779-2822 for other subscription options. Your first issue will arrive 4-6 weeks after your payment is processed, please allow additional time for overseas deliveries. Offer valid until December 30,2022.

LEFT BEHIND

Why do some games get abandoned by their developers? *Christian Guyton* investigates

We've all been there; watching a trailer for a newly-announced game, streamed live from a major show such as Gamescom or (should it ever return) E3, setting the mighty wheels of the hype train turning. 'What's the release date?' ask the fans. 'Coming soon', teases the pre-rendered reveal video. It's a hotly-anticipated title and the developers are remaining tight-lipped about their new project. Maybe you'll get a less-than-concrete release window in six months' time.

A year passes, then two, then three. Radio silence. No second trailer, no new screenshots, no dev diaries. If you're lucky, you might see a senior member of the development team pop up on social media, assuring eager fans—without any actual proof of life—that the game is very much still in production. However, nothing arrives and, a few more years down the line, the game is either quietly canceled, repurposed into something very different, or left in unspoken limbo forever.

This isn't exactly a common occurrence, nor is it unique to the games industry; plenty of films and TV shows stagger through early production but never see the light of day. Likewise, plenty of games survive a troubled development process to produce a satisfying end result. But 'development hell' has become a frequently used phrase in the gaming sphere, with some developers seemingly unwilling (or unable) to commit to canceling a game outright.

Stumbling to a full release is no guarantee a game will live on, either. Some titles manage to hit the store shelves (both physical and digital) before collapsing under their own weight months or even weeks after release. In cases like this, it's harder for developers to escape rigorous scrutiny from their player base, even in situations where a lack of support for a game is understandable.

In this feature, we'll be looking at some of the highest-profile cases of 'game abandonment', like a sort of Child Protective Services for neglected PC games. What leads developers down a path to dropping support for a game or choosing not to release it at all? It's time to find out.

© GETTY IMAGES/SOUTH AGENCY

Let's start with the big one, a game that has endured a lengthy saga of players versus publishers, complete with heroes, villains, and a rollercoaster of events that left passionate fans with emotional whiplash. We're referring to *Titanfall 2*, the celebrated sequel to a successful Xbox One launch title, from developer Respawn Entertainment and monolithic publisher EA.

Titanfall 2's release was hotly anticipated, with fans excited to see the game developing on the fast-paced action-shooter gameplay of the original and expanding across to other platforms. The first game sold over ten million copies in two years, a respectable sum for a new IP, and the second game was projected by EA to perform even better.

Early reviews confirmed EA's suspicions that they were onto a winner; the game received high praise for both its stellar single-player campaign—something that was absent from the multiplayer-focused original—and variety of online game modes. However, at first, sales were poor. Despite being a multiplatform release, *Titanfall 2* initially failed to sell as much as its predecessor, something that analysts blamed on EA's decision to launch the game in a crowded release window, between *Battlefield 1* and *Call of Duty: Infinite Warfare*.

Despite this underwhelming start, EA claimed to be happy with *Titanfall 2*'s retail performance and review scores, although Respawn Entertainment head Vince Zampella noted that it could have sold better. Still, it wasn't long before the game achieved a level of cult popularity, with a loyal player base that remained active enough for Respawn to continue releasing free content updates throughout the year following its release. These included a new cooperative game mode, multiple maps and weapons, and a massive heap of cosmetic items.

For a while, all seemed well. *Titanfall 2*'s player counts weren't mind-blowing, but the companies behind it continued to profit from the surprisingly fair micro-transaction system for cosmetic items. The game continued to flourish with relatively little input from Respawn until early 2019 when the developer released *Apex Legends*, a battle royale shooter set in the *Titanfall* universe.

AT THE APEX

Apex Legends was an immediate success, shooting to the top of the battle royale rankings alongside titans such as PlayerUnknown's *Battlegrounds* and *Fortnite*. Before the end of its first month, *Apex* hit a staggering player count of 50 million and as it grew in popularity, *Titanfall* fans became concerned that their game would be left behind. Respawn quickly refocused on their new success story, and any hopes of a *Titanfall* threequel seemed dashed.

Still, *Titanfall 2* held steady with respectable player counts. It wasn't hard to find an online match in any of the popular game modes, and *Titanfall 2*'s offline campaign was an enjoyable experience. The servers for both games remained online, and while some spin-offs never saw the light of day (*Titanfall Online*, a free-to-play shooter, and mobile game *Titanfall: Frontline* were canceled before the release of *Apex Legends*), all seemed well.

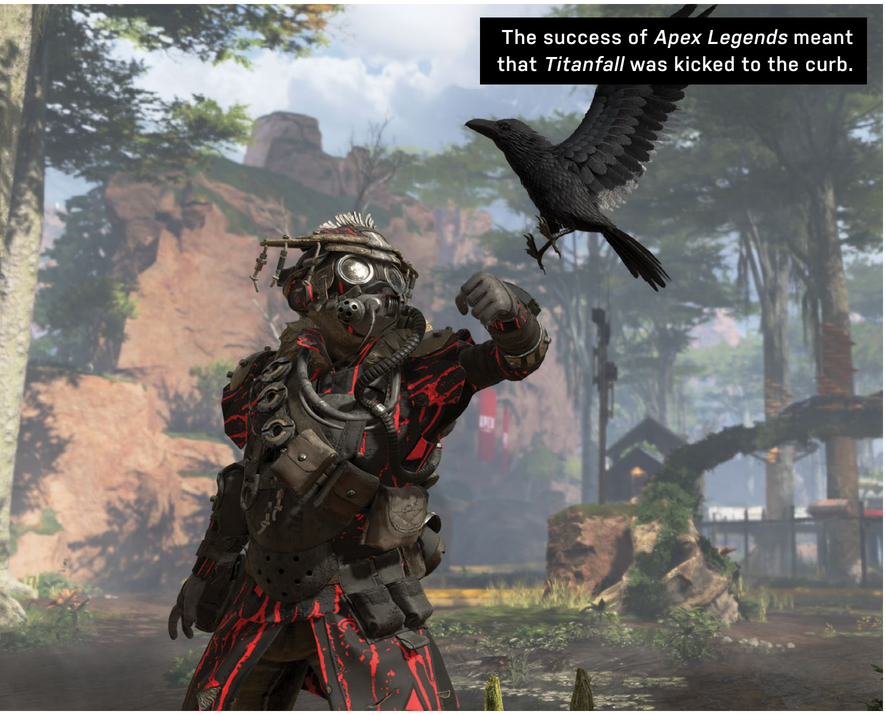
Titanfall 2 is still a cult classic, despite ongoing network issues.

Unfortunately, in mid-2021, things started to go badly wrong. The servers for *Titanfall* and *Titanfall 2* came under fire from hackers, who used a network of compromised systems to conduct continuous DDoS (distributed denial of service) attacks across all platforms. This rendered the multiplayer modes—which were sustaining most of the remaining player base—largely unplayable. The first *Titanfall* game had been under attack for years, with no patch appearing. Respawn eventually acknowledged the issues on Twitter, assuring players that a fix was on its way.

No such fix arrived, however, leaving fans to speculate that Respawn was finished with the series. These suspicions were reinforced when

Soldiers' Soul was the last *Saint Seiya* game released, over seven years ago.

© RESPAWN ENTERTAINMENT, BANDAI NAMCO



The success of *Apex Legends* meant that *Titanfall* was kicked to the curb.

another hacker, presumed to be unconnected to those DDoSing the *Titanfall* games, began inserting messages into *Apex Legends* directing players to 'savetitanfall.com'. Respawn enacted a fix for this within hours, drawing criticism from players who saw this as a case of favoritism. It was later confirmed that the Apex hack was perpetrated by fans who wanted to see *Titanfall Online* resurrected.

DO IT YOURSELF

One player, going by the moniker 'po358', posted a lengthy explanation of how to fix the DDoS issue on the online publishing platform Medium. In the post, po358 described their frustration at Respawn's apparent inability to repair the issues, before highlighting a number of key vulnerabilities and suggestions of how to fix them. Many of these had existed for years, with a stream of lower-profile hacks occurring in the original game, leading to an Overwhelmingly Negative user review rating on Steam. Still, Respawn did not release a patch.

The slew of DDoS attacks ebbed somewhat in late 2021, leaving the game playable in most regions, but the damage had already been done. Player counts for every platform had shrunk, and many matches were still troubled by disconnects and instability. In December, the DDoSers returned

What's that you're building there, a giant sausage-shaped spaceship? As you were...

PROBLEM CHILDREN

Let's be honest with ourselves: gamers can be a notoriously difficult bunch. The same can be said for virtually every audience within the entertainment industry, but toxicity and vitriol are often widespread in gaming communities, whether that manifests itself as homophobia-riddled region chats or outright death threats aimed at individual developers on social media. The echo chambers of subreddits and private Discord servers are no help, especially when they are populated by gamers who have little idea of how the game production process actually works, or worse, have huge misconceptions about how that process can realistically be conducted.

It stands to reason, then, that some games are shut down not due to any fault of the developers, but because the players themselves are simply uncooperative and unruly. One of the most infamous examples of this was *LEGO Universe*, a 2010 MMO from developer NetDevil, which saw players building in and exploring a collection of LEGO-themed worlds.

Despite initial successes and a player base that grew to 2 million within a year of release, NetDevil encountered an unforeseen problem: players simply wouldn't stop abusing the LEGO construction mechanics to build giant phallic objects.

The sheer volume of penis-shaped monuments forced NetDevil to pour money into active moderation, and even try to create 'dong detection software' to automate the process. Players tried to conceal their structures to evade filters, and NetDevil was forced to shutter the game less than two years after launch, citing 'unsatisfactory revenue'.

Another high-profile case came from the indie mobile world, with Dong Nguyen (creator of the legendary *Flappy Bird* game) announcing in 2014 that he was shutting down his game due to the guilt and stress caused by its 'addictive' nature and the way it brought out the worst in people. This revelation came after a number of *Flappy-Bird*-related assaults (and one viral murder hoax) were reported across the globe.

© NETDEVIL/THE LEGO GROUP, RESPAWN ENTERTAINMENT

with renewed vigor, making both games effectively unplayable once more. Player counts for the original *Titanfall* dropped so low that, before the end of 2021, Respawn announced that it was being pulled from sale and would no longer be available on subscription services.

That seemed like a final nail in the coffin for *Titanfall*, as even with the few remaining players migrating to *Titanfall 2*, all was not well. Fans openly mocked Respawn's repeated statements that *Titanfall* was the 'core of our DNA', decrying it as a slap in the face to the fanbase as long as the DDoS issues remained unfixed. Respawn declined to comment for this article, however, there's no doubt the studio is now operating on a higher level, with all its efforts catering to the larger player base (and revenues) of *Apex Legends*.

Fortunately, the tale of *Titanfall* does have a happy ending. Towards the end of 2021, following the return of the hacking scandal to *Titanfall 2*, enterprising modders released the 'Northstar client'. Taking its name from one of the in-game Titans, Northstar allows players to host their own *Titanfall 2* servers and play via a server browser rather than matchmaking, safe from DDoS attacks. The mod also offers a huge variety of adapted game modes and other fun features never implemented in the original game. This has seen thousands of players return to mech-stomping action on PC (sorry, console players).

SOLE SOLDIER

A passionate fanbase can move mountains, and that's the hope of fans of the long-running anime and manga series *Saint Seiya*. The original series, released in 1986, featured magical warriors engaged in a war against the Olympian pantheon of deities and a game for the Nintendo Entertainment System was released in Japan a year later.

Since then, *Saint Seiya* has seen a number of adaptations, with 18 games across numerous platforms and a whole bunch of arcade and pachinko spin-offs in Japan. The most recent title was the fighting game *Saint Seiya: Soldiers' Soul*,

Beyond Good and Evil 2 was greenlit in 2008, but fans heard nothing until 2017.

© UBISOFT

LOST AND DAMNED

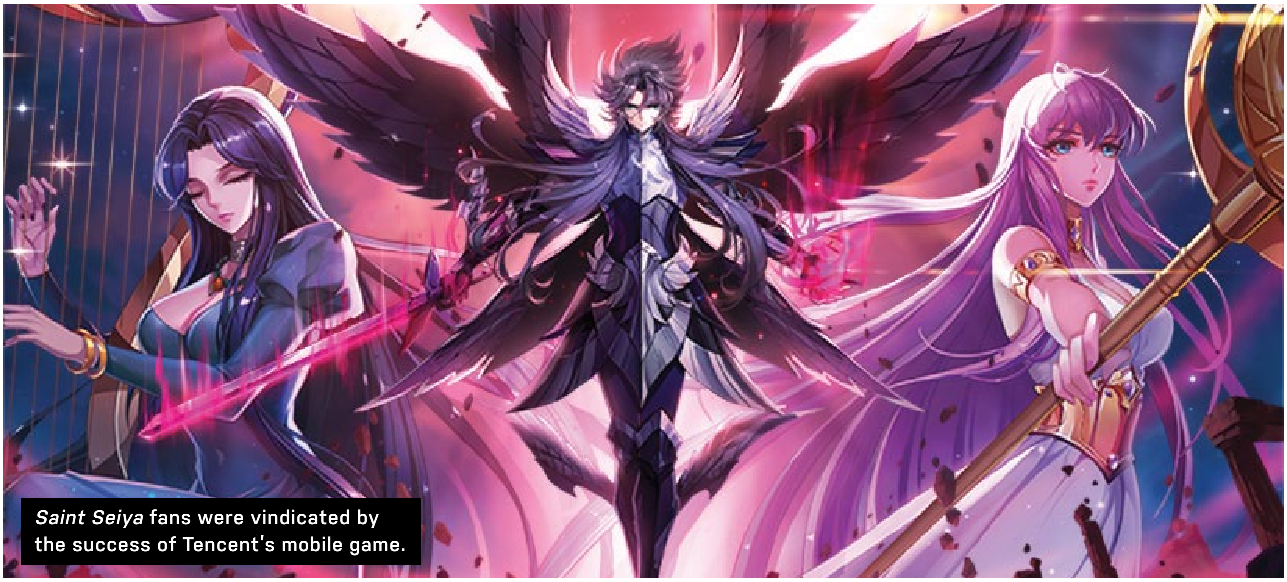
It's always sad news when a game gets canceled, but some titles don't even get that closure, remaining on development death row indefinitely. The term 'development hell' was coined long before the rise of the games industry, referring to media that ends up trapped in a state of limbo for any number of reasons, whether due to lack of funds, creative differences, legal disputes, or something else entirely.

The tech and gaming industry actually has its own term for projects like this; 'vaporware' refers to games and software (and sometimes hardware) that is officially announced but releases late or doesn't release at all. Some games stagger through development hell only to be released in a lackluster final form, such as the infamous *Duke Nukem Forever*, which spent a whopping 15 years in development and went through multiple different game engines and development teams. Despite a decade and a half of hype, *Forever* tanked with terrible review scores and unimpressive sales figures, potentially killing the *Duke Nukem* IP forever (pun intended).

Another hotly-anticipated game that may never get released is *Beyond Good and Evil 2*, a prequel to the legendary 2003 action-adventure title. Although the original was considered a commercial failure, it reviewed well and gained enough of a cult following for Ubisoft to greenlight a second game from creator Michel Ancel (of *Rayman* fame). This was back in 2008, and fans heard nothing until a re-announcement at E3 in 2017, where Ancel confirmed that previous clips and screenshots were from a ditched version of the project.

In 2020, Ancel retired from game development, leaving many fans concerned about the fate of the game. Coincidentally, Ancel had also been working outside of Ubisoft on a survival game named *Wild* (announced in 2014) that had also been labeled as vaporware by some journalists. Ancel was keen to stress that both games would remain in development without him, and *BGaE2* was confirmed as 'still in development' by Ubisoft in 2021, but no release date nor new gameplay footage has surfaced yet.

One game that many are hoping will be released one day is *Scalebound*, which officially began development in 2013. A dragon-riding RPG from developer PlatinumGames, it was canceled in May 2019 after a troubled development period, to the dismay of fans. Still, Microsoft remains the holder of the *Scalebound* IP and Platinum's head designer Hideki Kamiya confirmed in a recent interview that he was 'totally serious' about resurrecting the game should he get the chance.



Saint Seiya fans were vindicated by the success of Tencent's mobile game.

released for PlayStation and PC in 2015, developed by Osaka-based studio Dimps, with licensing and publishing provided by Bandai Namco.

Soldiers' Soul was beset with issues from day one on PC, with the developers only releasing a single patch shortly after release to fix a bug that prevented offline play. Beyond that, there was no new content, no balance changes, and essentially no communication from either Dimps or Bandai Namco. Online play was buggy, laggy, and generally unstable, and the game ran poorly, even on high-end hardware due to bad optimization.

One active member of the *Saint Seiya* gaming community, going by the handle 'Mu the Guardian', published their own in-depth guide to combat the debilitating network lag and instability in *Soldiers' Soul*, including advice on router port forwarding, adding code strings to the game's Steam launch options, and modifying settings in the game's Config file to improve performance. Mu is also involved in the running of local unofficial tournaments in Canada and Italy, where players can compete without fear of connection issues.

GUARDIAN GAMES

Mu expresses frustration with Bandai Namco for its lack of communication regarding the poor state of *Soldiers' Soul*, a sentiment echoed by other members of the community. DrNoD10 claims that 'Bandai just launches [*Saint Seiya* games] and does nothing, no updates, no new content, nothing', while XionShinah says, 'Bandai needs to improve its game support system', noting that it is nigh-impossible to get help from the publisher with these issues.

Everyone agrees that a new *Saint Seiya* game on PC and consoles would be well-received by its small but dedicated fanbase, who have petitioned Bandai Namco and original license holder Toei Animation for a new game on change.org. They say that a working re-release of *Soldiers' Soul* would be sufficient, but even that seems unlikely, with Bandai Namco's license to produce *Saint Seiya* games expiring in 2021, following the shutdown of its mobile title *Saint Seiya: Shining Soldiers*. Bandai Namco did not respond to our request for comment.

Still, all hope is not lost. Publisher Tencent released free-to-play game *Saint Seiya: Awakening* for mobile devices in 2017, and it went on to achieve over five million downloads worldwide, proving that interest in *Saint Seiya* games is still alive. Mu says fans have requested that Tencent begins development on a new mainline game for PC and consoles, with Tencent reportedly 'open to the idea'.

TOWNSHIP HARDSHIPS

An older game that suffered from a lack of developer support was *Towns*, released during Steam's surge of popularity in the early 2010s. Billed as a town-builder in the vein of *Dwarf Fortress*, *Towns* saw players assembling a settlement and catering to roving adventurers. It was one of the first games to be approved for sale through Steam Greenlight (later Steam Direct), a system that enabled players to vote on which games they'd like to see supported on Valve's digital storefront, creating self-contained crowdfunding campaigns for indie studios.

Greenlight's decision to allow developers to publish beta builds drew criticism from gamers,

FRIDAY THE 13TH
THE GAME

Legal issues between Jason's original creators led to *Friday the 13th: The Game* being essentially abandoned.

Towns sold more than 200,000 copies on Steam in its unfinished beta state.

© SMP, TENCENT, GUNMEDIA

who argued that it encouraged developers to release unfinished games—*Towns* was perhaps one of the most egregious examples of this. Three-man dev outfit SMP confirmed upon release that the game would continue to be updated, but that didn't stop players from review-bombing *Towns*' Steam page, claiming it was a 'buggy, barely-playable mess' that shouldn't have been released.

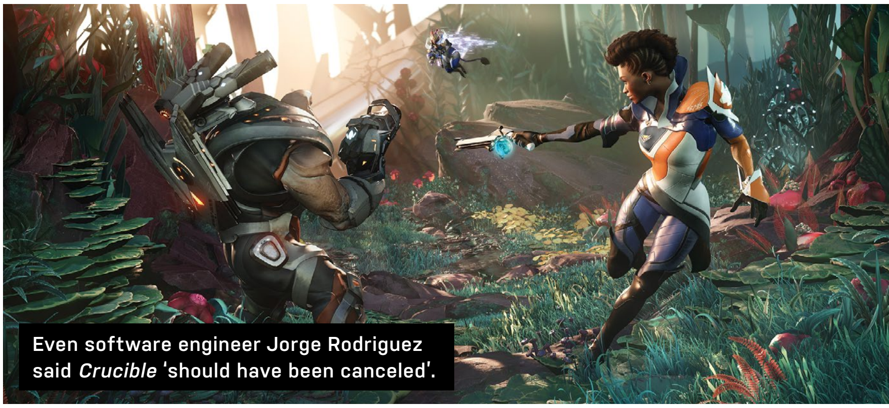
Despite these warnings, *Towns* quickly sold over 200,000 copies at $15 apiece, resulting in an angry player base of significant size. Lead developer Xavi Canal announced in February 2014 (a year and a half after the game's release) that he was quitting due to burnout, resulting in further vitriol from those who had shelled out for *Towns*. Replacement dev, Florian Frankenberger, took up the reins only to end development completely four months later.

Frankenberger stated that development was being halted due to a lack of ongoing purchases; to put it simply, the game wasn't profitable anymore. This raised many questions about when a developer should abandon support for a game, although most hopeful *Towns* fans naturally didn't see it that way. Claims that the developers had 'taken the money and run' were common, and the game still sits for sale on Steam, forever unfinished with a Mostly Negative user review score.

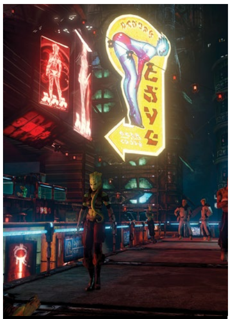
ADMITTING DEFEAT

The debate on how long developers should be expected to support their games is likely to rage on, with disgruntled gamers expecting their favorite titles to remain playable until the last player has logged off. Of course, this isn't practical, as game publishers have to take other factors into account—broadly speaking, there are three things that developers and publishers must consider when the question of ending support for a game arises.

The first is the most straightforward: money. How much is it costing to keep the game running? How much does the game earn in terms of sales, subscriptions, or micro-transactions? As anyone who has worked in the games industry will confirm, money is almost always the driving force behind any such decisions.



Even software engineer Jorge Rodriguez said *Crucible* 'should have been canceled'.



Prey 2 promised an alien cyberpunk city to explore, but was eventually reborn as a totally different game under Arkane Studios.

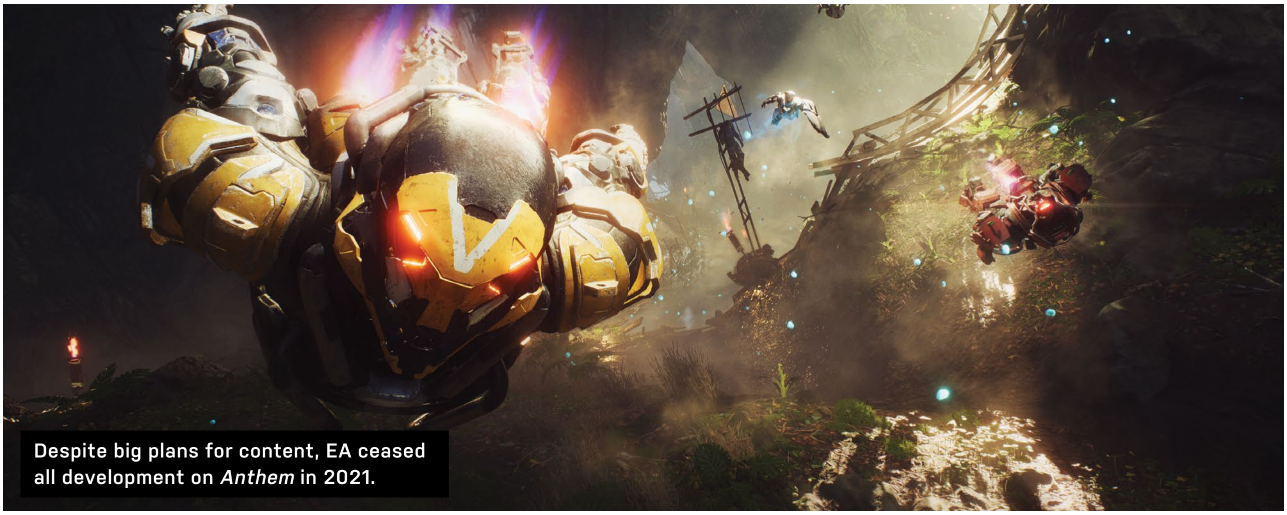
The second and third factors are more nuanced; what are the potential PR issues, and what would any staff working on the game do once it has been shut down? Even if a game isn't as profitable as it once was, a publisher might opt to sustain it if the alternative could create a PR disaster—provided, of course, that doing so won't actively cost the company money. Some publishers may hold off on ending support for a game because of the potential damage to their reputation.

Finally, development studios have limited manpower and employees may be required to work on other projects. If a game is 'dying' and the studio needs to put out a new title on schedule (usually to meet financial demands), it stands to reason that staff can be pulled from supporting an old game to complete an ongoing project on time.

TROUBLE BREWING

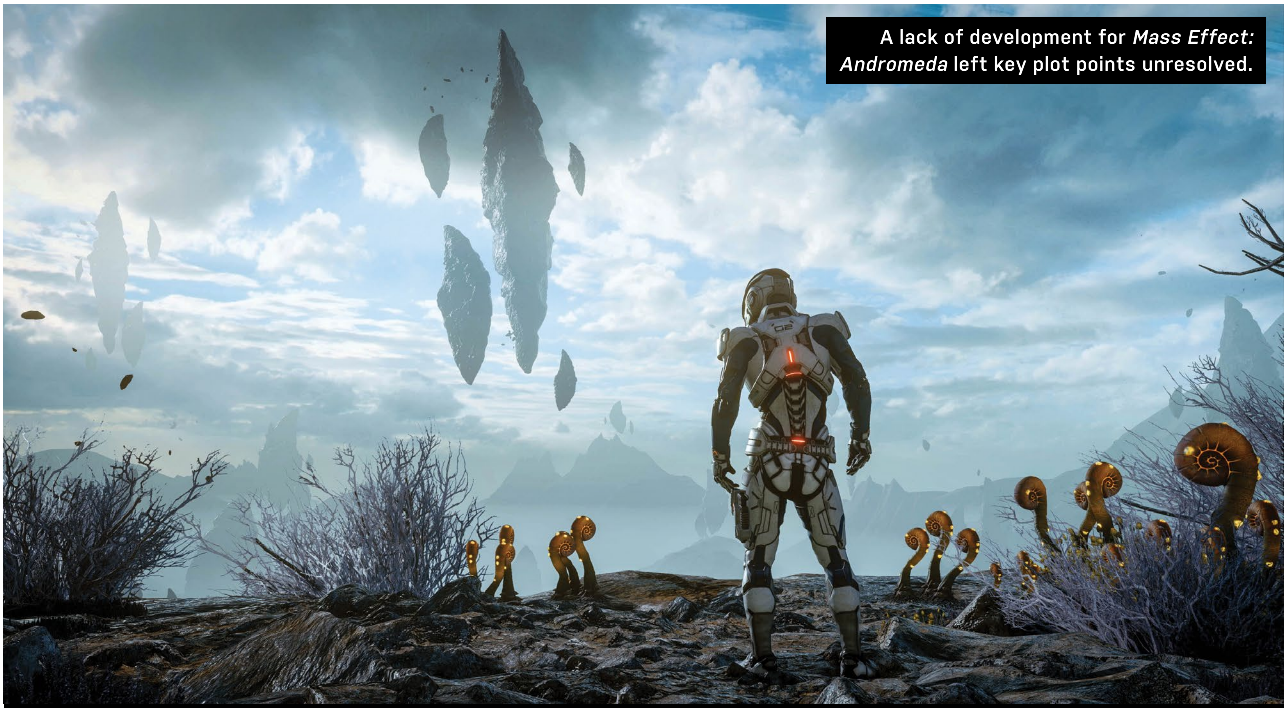
In rare cases, unusual circumstances can bring work on a game to a grinding halt. These are often difficulties of a legal nature; disagreement between media license holders and developers has forced many a game adaptation into cancellation, such as Disney opting not to renew its trademark for the assumed-canceled *Star Wars 1313* spin-off game.

One case of legal proceeding impinging ongoing support for a game is that of *Friday the 13th: The Game*, a multiplayer survival horror game



Despite big plans for content, EA ceased all development on *Anthem* in 2021.

© BIOWARE/EA, AMAZON GAME STUDIOS, BETHESDA



A lack of development for *Mass Effect: Andromeda* left key plot points unresolved.

GETTING CLOSURE

In cases when a game has been canceled or left unsupported, fans are usually left with nothing to fill the void. There have been rare cases, however, where publishers have seen fit to release additional media outside the game to tie up loose ends. One such example was *Mass Effect: Andromeda*, the fourth entry into BioWare's beloved sci-fi series. *Andromeda* suffered from a buggy launch version and character writing that many fans felt was lackluster compared with the original trilogy, dooming it with mediocre review scores from the outset.

Although BioWare worked quickly to patch the game's worst issues, it underperformed in sales and the Edmonton-based team was reassigned to work on the studio's new IP, *Anthem* (which ironically also bombed on release). Attacks on social media targeting individual members of the dev team and EA staffers further muddied the water, forcing BioWare to release a statement that branded the behavior as 'unacceptable'.

Fans were left waiting indefinitely for *Andromeda* DLC that never arrived, leaving a number of key plot points unresolved; mostly revolving around the Quarian Ark, a giant spaceship that had gone missing sometime before the start of the game and which had been expected to make an appearance in a future content expansion pack.

BioWare officially confirmed in August 2017 that no DLC for *Andromeda* would be released, but there was a silver lining to this cloud: a trilogy of prequel books set in the *Mass Effect: Andromeda* universe, exploring a range of stories prior to the events of the game. The last of these, *Annihilation*, would explain the fate of the Quarian Ark, with author Catherynne Valente offering some canonical closure to fans who wanted more. The *Mass Effect* series will continue despite the misstep that was *Andromeda*, with BioWare announcing in 2020 that a veteran team of developers was working on a new game.

featuring the hockey-masked horror icon Jason Voorhees. With a pre-built player base of classic horror fans, initial performance in 2017 was solid if not spectacular, and players expected plenty of post-release content drops, including plans for new game modes and cosmetic items.

Through no fault of game publisher GunMedia, the slasher game had to be put on hold as a result of a legal battle in 2018 between *Friday the 13th* co-creators Victor Miller and Sean Cunningham (screenwriter and director of the original movie). Miller claimed he was the owner of the *Friday the 13th* IP, which was disputed by Cunningham, who had greenlit the game's production. With ongoing lawsuits over intellectual property, GunMedia was forced to cancel all planned updates. Although the publisher continued to release bug fixes, fans were left out in the cold.

Miller won the lawsuit, but the damage was done; dwindling player counts saw GunMedia shutter the game's dedicated servers and end ongoing support in 2020. Peer-to-peer matchmaking remains an option, but with fewer than 200 active players on average, the future looks bleak.

We could go on: Bethesda's lost *Prey 2* prototype that eventually emerged as the brilliant 2017 *Prey* reboot; Amazon Game Studios shutting down its ill-fated attempt at hero shooter *Crucible* less than six months after release; the catastrophic failure that was BioWare and EA's massively-hyped *Anthem*. Wikipedia's 'canceled video games' category page offers hundreds of entries, many of which never made it beyond early development. As gamers, all we can do is hope that our own favorites won't get dropped—and if they do, graciously accept defeat and move on to pastures new.

© BIOWARE, EA

CENTERFOLD

1 FEATURE-RICH

As well as looks, the Beoplay Portals provide plenty of compatibility and functionality. With touch sliders and gesture controls on each cup, it's easy to control your audio on the go. Alternatively, you can control the headphones via the app, which allows you to fine-tune the sound EQ and switch profiles when you're listening to music or gaming.

Bang & Olufsen Beoplay Portal

BANG & OLUFSEN IS ACCUSTOMED to making premium headphones, so it's no surprise that the Beoplay Portals are another high quality offering. However, with these headphones, B&O is aiming to conquer two markets—offering a high-end, rich-sounding peripheral that doubles as a gaming headset with a built-in microphone. With plenty of connectivity, features, and compatibility, this is the only headset you'll need for music, streaming, and gaming.

The Portals offer a rich, warm, and detailed soundscape that oozes quality. As a gaming headset, you get 3D audio with pinpoint directional audio but, thankfully, instead of opting for a more gaming-focused aesthetic, B&O has kept the same design as the rest of its range.

The Portals come in three colorways—we'd say that the grey mist option of our review pair (pictured) is the pick of the bunch, though the black anthracite and navy blue alternatives are hardly eyesores. It's safe to say that this headset ticks all the boxes for music consumption, gaming performance, and looks. While the dual-use means you get the best of both worlds, this premium experience does come with a premium price tag, which is $499. –SAM LEWIS

2 MATERIALISTIC

To match the high-end design, you'd expect a similar quality of materials and that's certainly the case with the Portals. The earpads are made of soft lambskin leather, while a bamboo knit headband cushions the top of your head. The main construction is aluminum and even the plastic parts are soft to the touch, matching the craftsmanship B&O has put into these cans.

3 EFFORTLESS COMFORT

Weighing just under 0.7lbs, you can wear this headset for a long time before comfort or overheating become an issue. There's a balancing act when creating a comfortable, lightweight headset—it can potentially feel cheap, but that's not the case here. The company's choice of materials makes these cans feel great, even in warm conditions.

SEE REVIEW PG. 78
ALIENWARE

Dell's new Alienware 34 AW3423DW OLED panel is the best gaming monitor yet.

SCREEN TECH IN 2022

OLED monitors are here at last. But as *Jeremy Laird* reveals, you can expect plenty more panel tech in 2022

NAILING DOWN the exact launch date of the very first color LCD monitor for the PC isn't easy. But one of the earliest was certainly the NANAO F-1020 from Eizo. Launched way back in 1993, the F-1020 spanned a mighty 10.4 inches and rocked no fewer than 640x480 pixels. Count 'em!

As it happens, by Eizo's own estimations, it was a sales flop. Yet here we are nearly 30 years later drowning in LCD panels. The technology absolutely owns the PC monitor market. But is everything about to change? The arrival of the awesome new Alienware OLED gaming panel (see page 78) certainly suggests so.

At last, per-pixel lighting is actually a thing for the PC and not just smartphones and TVs. Plus far faster response, not to mention much better pixel response, and... we're getting ahead of ourselves. The reality is that OLED isn't going to assimilate the monitor market overnight. What's more, LCD technology still has plenty more to give.

So, yes, the story of the PC monitor in 2022 is likely to be one of a technological turning point, the beginning of the end for LCD panels. But even if that is the overarching narrative, there are plenty of other subplots to enjoy, including 8K awesomeness, ridiculous refresh rates, and a whole lot more besides.

LET'S MAKE ONE THING perfectly clear. LCD is a terrible technology for a full-color display. Truly, it could hardly be less suitable. The basics involve shining light through a small aperture containing liquid crystals, the latter changing orientation in response to an electrical current.

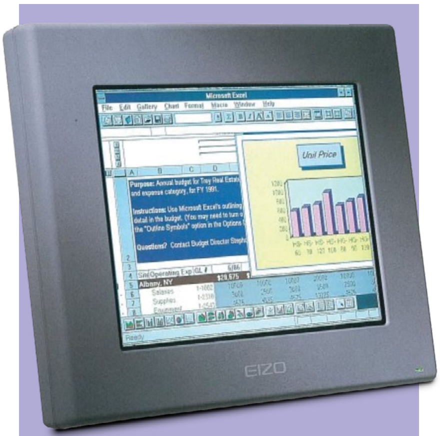
That enables light to either pass through or be blocked. Put three of these tiny, independently controlled "subpixel" windows together—one red, one green, and one blue respectively—and you have a system that, in theory, can render any color. The critical phrase here is "in theory". Because in practice, LCD has several fundamental issues.

For starters, the fact that liquid crystals have to move at all immediately introduces latency. It takes time for the position or state of the crystals to move in response to a change in current. That process may be quick, but it is never going to be instant. Similarly, while the amount of light passing through each subpixel is limited according to the crystals' orientation, it is never fully blocked. Some light always leaks through.

Making matters worse, the amount of visible light that escapes varies depending on your vantage point. Typically, maximum light blockage takes place perfectly perpendicular to the panel surface. But from any given viewing point, that will apply to only a small portion of the display. As you look around the display, you are viewing each point of the panel from a slightly different angle. So you get both apparent variances across the display from a fixed position, and changes in brightness and color if you move position.

To cut a long story short, LCD monitors have fundamental issues with response, contrast, color control, and viewing angles, which is pretty damning of the technology. In that context, what's most remarkable is just how good LCD tech has become since that seemingly inauspicious NANAO F-1020 monitor.

Today, pixel response is measured in fractions of a millisecond, the viewing angles of the best IPS monitors are good enough to be a non-issue in many scenarios, color fidelity is measured in billions of hues, and the introduction of full-array backlighting is finally solving the contrast conundrum.



Back in 1993, the Eizo F-1020 was one of the first flat panel monitors for the PC.

Indeed, it is actually possible to almost entirely fix that final issue of light control and contrast. The trick is to put two LCD panels together in a sandwich, both of the same headline resolution. You can then use the rear panel to act as a per-pixel dimming array, allowing most of the light to be blocked before it reaches the primary panel and, in turn, dramatically improving black levels, contrast, and HDR performance. The catch? That's an incredibly complex setup that introduces a whole new layer of display modulation. It requires algorithms to control the dimming panel, which can cause image problems of their own.

DELAYED RESPONSE

None of that, of course, addresses the other major failing of LCD technology—response. Impressive quoted response times claimed by the latest gaming panels are, in truth, fairly fictional. The standard measure of pixel response used by most monitor makers and referred to as 'gray-to-gray' ignores the first 10 percent of the transition from one color to another and also the last 10 percent. Only the middle 80 percent is measured, which just so happens to be the bit that occurs the fastest. The full response time can be 10 times or more slower. In other words, the true response time of a 1ms LCD monitor may actually be 10ms.

The good news is that the answer to pretty much all these problems has finally arrived in 2022. Strictly speaking, the Alienware AW3423DW isn't the first

THE ULTIMATE DISPLAY TECHNOLOGY
BUT YOU'LL HAVE TO WAIT FOR IT

It's the flat panel to rule them all, the ultimate display tech—we give you MicroLED. But it's not coming to the PC anytime soon. It's still years away, which is a pity because when it does hit the PC, it's going to be awesome.

Like OLED, MicroLED is a self-emissive technology that offers true per-pixel lighting. So, each individual pixel can be turned off completely. That means essentially infinite contrast and true black tones. The difference is that MicroLED sidesteps organic compounds and so doesn't suffer from burn-in. The latter is a major issue with OLED displays because of the differential degradation within the RGB subpixels.

In an OLED panel, the blue subpixels wear out faster than the red and green subpixels. That eventually causes permanent color distortion seen as burn-in. It's a problem that's particularly tricky on the PC due to persistent on-screen elements such as the Windows taskbar, a prime candidate for burn-in.

Of course, the latest OLED panels have numerous mitigating strategies for reducing burn-in. Samsung, which supplies the panel for the new Alienware OLED gaming monitor, and Alienware's parent company Dell are both confident it won't be an issue to the extent that they provide a three-year warranty covering any burn-in issues.

However, burn-in isn't MicroLED's only advantage. It also supports peak brightness right across the entire panel, whereas OLED can only achieve that in small isolated patches of the screen. An OLED panel with a peak local brightness of, say, 1000 nits can typically only hit around 150 of full-screen brightness.

The consequence is that even the latest OLED panels struggle with really bright scenes in HDR content, suffering from clipping and loss of detail. OLED is at its best in HDR terms when the screen is mostly dark with a few small and bright objects. MicroLED solves that problem and will be by far the best performing panel tech for HDR content.

© EIZO

The Gigabyte M32U delivers 4K and 144Hz in a relatively affordable 32-inch, IPS package.

PC monitor based on OLED technology. But everything that's come before has either been the equivalent of that early Eizo LCD panel—a glorified beta test at the buyer's expense—or a mega-money monitor aimed at narrow professional applications. The Alienware is the first consumer-ready, minimal compromise, affordable OLED PC monitor.

It's also miles faster, in terms of pixel response, than any LCD monitor. It has essentially perfect contrast, thanks to each pixel containing its own independent light source, plus with none of the blooming, and thus incredible low range HDR performance. And its viewing angles are virtually flawless. It is, surely, the best gaming monitor we've ever seen, but that doesn't make it the best all-round monitor you can buy. It isn't even close to being the best option for most productivity tasks. As you'll see from our review on page 78, the AW3423DW isn't perfect.

Some of the ways in which OLED panels aren't perfect will ensure that LCD monitors remain relevant for some time. The first is resolution. At 3,440x1,440 pixels and under 110dpi, the Alienware AW3423DW has decent pixel density for gaming. Some would argue it's pretty much perfect for a 34-inch ultrawide gaming monitor, just the right balance between visual detail and allowing for

So, why isn't MicroLED coming to the PC soon? In a word, money. MicroLED remains very expensive, as in $80,000 for the cheapest currently available MicroLED TV.

There are numerous reasons why, but one of the most intractable involves the existing 'pick and place' manufacturing technique for MicroLED panels. It essentially means each MicroLED subpixel is being individually installed on the MicroLED backplane. On a 4K panel, that's no fewer than 24 million MicroLEDs.

It's one reason why existing MicroLED screens are currently made up of multiple panels. That makes broken pixels less of an issue if part of the panel can be replaced. That 'pick and place' method also puts a lower limit on pixel density. Consequently, the smallest 4K MicroLED screen produced so far is a Samsung 75-inch model.

Looking to the future, the great hope is that inkjet-like printing processes can be used to lay down MicroLED pixels, en masse. If that happens, costs will plummet dramatically.

Cheap at $80,000: Samsung Wall MicroLED TV is far from mainstream adoption.

But even taking the most optimistic view of MicroLED manufacturing tech, we're at least five years away from moderately affordable TVs. MicroLED PC monitors with sufficient pixel density to replace LCD technology and cheap enough that normal people can afford them? They're even further out than that. What a pity.

© SAMSUNG, GIGABYTE

high frame rates. More pixels would deliver greater detail but at the cost of zingy frame rates and low input latency.

We wouldn't disagree. But we'd also point out that there's much more to PC usage than gaming. For almost everything else, more pixels is usually a good thing. While high-resolution mainstream OLED monitors will likely come on stream in the next few years, we're not expecting anything affordable in 2022. Of course, right now, you can now get a 4K 27-inch monitor with around 160 pixels per inch for little more than $200. With that 160dpi, you get crisper fonts and more image detail than a 110dpi panel such as the Alienware OLED.

Of course, by today's standards 27-inches is relatively puny. Which is where one of the big trends of 2022 steps in. This year, 32-inch 4K monitors with high refresh are going to be a thing. Until the latter half of 2021, 4K with high refresh was limited to 27-inches. But this year, the market is going to be flooded with monitors like the Gigabyte M32U. That's a 4K, 32-inch IPS model with 144Hz refresh support.

The M32U can currently be had for around $600. So, it's actually relatively affordable, which isn't something you can say of most things in 2022. What's most promising about the Gigabyte M32U and competing monitors like the ASUS ROG Swift PG32UQ is that they make for outstanding all-rounders. You get all that 144Hz gaming goodness, plus a fantastic 4K pixel grid for epic productivity, plus nice, sharp fonts.

To put this appealing 32-inch IPS monitor class into context, the only comparable and currently available 32-inch OLED monitor is the LG UltraFine 32EP950, which is limited to 60Hz and costs $4,000. LG has said it plans to release a high-refresh 32-inch 4K OLED model in the future. But there's no date, no price, no nothing. We don't expect anything soon and predict that when it does arrive, it won't be cheap.

Perhaps more promising is similar news from AU Optronics, the Taiwanese manufacturer of LCD and OLED panels used by a wide range of TV and monitor makers. AU doesn't produce actual TVs and monitors, just the panels that go into them. AU tends to price its panels aggressively, allowing monitor makers to hit lower price points than they otherwise would buying panels from some of the other big suppliers, such as LG and Samsung. And AU has plans for a 32-inch, 4K, 144Hz OLED panel. Again, there's no date or further information. So, it seems unlikely that we'll see a high fresh 4K OLED monitor this year. But it's coming.

Dead end display: Dell's UltraSharp UP3218K of 2017 is still the only vaguely mainstream 8K monitor... for now.

As it happens, AU also says it is tooling up for something even more spectacular, namely an 8K, 32-inch, 120Hz OLED monitor. Again, don't expect to be buying a monitor based on this panel anytime soon, but it is a thoroughly tantalizing prospect. It also brings us neatly to the next big trend for 2022. Yep, 8K.

8K, ON THE WAY?

Now, an entirely justified immediate reaction to the notion of 8K would question the point of it. After all, there's virtually no existing 8K content when it comes to movies and TV shows. There's barely any streaming content available in 8K, beyond demo reels. Likewise, although most games can render at 8K, it generates literally four times the load of 4K. And only the most powerful current GPUs can kick out decent frame rates at 4K, let alone 8K. It is true that both AMD and Nvidia's next-gen GPUs, due later this year, are expected to be a huge leap forward in terms of performance. But even if they do deliver the rumored 2-2.5x boost in performance, that's not enough to offset the huge additional rendering load 8K generates over 4K.

So, 8K isn't about watching movies. It's not about playing games. What it is about, however, is pixel density. It's debatable exactly how many pixels you need per inch before each individual pixel becomes invisible to the human eye and further density becomes redundant. Visual acuity varies from person to person. Much depends on the device being used,

CONNECT FOUR
DISPLAYPORT AND USB UPS THE ANTE

As resolutions and refresh rates climb ever higher, display interfaces are becoming more critical than ever. Already, it's only the very latest AMD and Nvidia graphics cards that can drive a 4K display at 120Hz over HDMI. At full 4:4:4 chroma and 8-bit color, that requires fully 32Gbps of raw bandwidth.

Now imagine what's required for 8K and the usual 60Hz. Then double that for 8K 120Hz. Now we're talking crazy numbers. As it happens, both HDMI 2.1 and DisplayPort 1.4 have the bandwidth minerals, so to speak, for 4K at 120Hz, but compression is required for 8K@60Hz. HDMI 2.1 can actually go as high as 10K (10,420x4,320 pixels) with compression.

Anyway, once you also factor in the bandwidth requirement of HDR, it's clear that new interfaces are going to be required soon enough.

For the PC, that means DisplayPort 2.0. It increases bandwidth over the existing DisplayPort 1.4 standard from 32.4Gbps raw and 25.92Gbps effective to fully 80Gbps raw and 77.37Gbps effective.

So, it can go beyond 60Hz at 8K without compression, along with supporting 8K at 60Hz with HDR and 144Hz 4K with HDR. As for what it can achieve with compression, how about a 16K panel? Nice.

The other critical piece of the connectivity puzzle is USB. Already, USB-C with DisplayPort alt mode is becoming extremely popular thanks to its ease

© DELL

LG UltraFine™ Display
OLED Pro
LG

The LG UltraFine 32EP950 is a 4K OLED PC monitor, but it costs $4,000 and is only 60Hz.

viewing distances, and so on. But when it comes to desktop monitors, and much as it pains us to admit it, Apple probably has it right with its so-called Retina displays.

Those clock in at 200dpi minimum. That's significantly higher than the 160dpi of a 27-inch 4K monitor or indeed the 140dpi of the 32-inch 4K class. When it comes to things like super-crispy font rendering and image detail, however, high DPI really makes a difference. Go to something bigger like a 40-inch 4K display and the result is a chunky 110dpi, the same as that Alienware OLED gaming panel. 8K also allows you to view 4K content at full resolution with plenty of screen real estate left over for toolbars and timelines.

When it comes to PC monitors, you currently have a choice between a reasonable but perhaps not quite true high-DPI experience from smaller 4K monitors, or a larger display with big, fat pixels. The closest thing to an exception is the Dell U4021QW, a 40-inch ultrawide panel with 5,120x2,160 pixels. But even that is only 138dpi.

The answer is 8K. For an idea of just what's possible with 8K, try this for size, literally. A 55-inch 8K panel has more or less the same pixel density as a 27-inch 4K monitor. In fact, it is more or less four 27-inch 4K panels joined together. As it happens, you can get a 55-inch 8K TV for about $1,000 and drive it at 60Hz over HDMI 2.1 provided you have either an Nvidia GeForce 30 Series GPU or one of AMD's Radeon RX 6000 graphics boards. That sounds appealing, right?

The problem is that every 8K TV on the market uses the BGR, or Blue-Green-Red, subpixel structure rather than RGB (Red-Green-Blue), the latter being the standard for PC monitors. That matters because software, including the Windows operating system, leans on the RGB subpixel structure to effectively create a higher addressable resolution in some scenarios, especially font rendering. Microsoft's ClearType font smoothing tech does just that. And it doesn't work correctly by default with the BGR subpixel structure.

Without getting bogged down in detail, it is possible to set Windows ClearType to address BGR subpixels rather than RGB and enable correct rendering. But some applications don't respect ClearType's global settings, including Chrome, so you can end up with a mishmash of correct and incorrectly rendered fonts.

Even though Dell launched the 8K UltraSharp UP3218K way back in 2017, it remains virtually alone in the market as an 8K monitor rather than TV, still costs

Hmmm, upgrades: USB is about to get a 240W power up, plus more bandwidth

of use and ability to deliver power, allowing a single cable to connect a laptop, drive the display, charge the laptop itself and connect peripherals. As resolutions and refresh rates increase, of course, USB will need to keep up.

As it is, the existing USB 3.2 standard tops out at 20Gbps. But USB 4 doubles that to 40Gbps, significantly increasing your display options.

Just as important, the USB Implementers Forum recently announced a new Extended Power Range (EPR) definition known as USB-PD R3.1. This promises to increase the maximum power delivery for USB-C charging from 100W to fully 240W. The existing 100W limit isn't nearly enough for powerful gaming laptops. But the increase to 240W will make it truly viable to run a high-performance portable via USB-C.

The only snag is that delivering that much power creates some practical problems. To prevent shorting and arcing, especially when unplugging, new cables are required.

Part of the solution is to make the CC and VBUS pins different lengths, thereby allowing the detection of disconnect events quickly enough to enable the power source to reduce current before the cable is completely disconnected.

A snubber capacitor installed at both cable ends is also part of the new EPR standard and this will help to ensure the new turbocharged USB interface doesn't send sparks flying every time you pull the plug.

© LG

nearly $4,000, and runs off DisplayPort 1.2 rather than DisplayPort 1.4 and HDMI 2.1. So, you have to connect via dual DisplayPort 1.2 interfaces just to get 8K at 60Hz. Seriously clunky.

That's all set to change this year. BenQ says it will launch its first 8K monitor later in 2022 and Viewsonic's is due soon after. It's not clear exactly how they'll be priced, but we're fairly confident it will be well below that $4,000 Dell. What's more, both Hannspree and Monoprice, both known for their competitive pricing, have hinted at 8K panels in the works. Hannspree has suggested its 8K monitors will be bigger than existing displays.

It's unclear exactly what it plans, but we suspect it could be a 55-inch monitor using a TV panel rotated through 180 degrees to give the correct RGB subpixel layout. Add in HDMI 2.1 and DisplayPort 1.4, crank it out for, let's say, $1,500 and that's still not chump change for a PC monitor. But what a display that would be. Well worth investing in for years of high-DPI action with an incredible amount of desktop real estate to boot.

While we're talking resolutions, one option is the upcoming LG DualUp 28MQ780. It's an unusual 16:18 aspect panel with 2,560x2,880 pixels and is designed to deliver increased vertical space in a world of ubiquitous widescreen monitors. A niche option? For sure, but interesting all the same.

If that's affordable high-refresh 4K and 8K multi shapes and sizes covered off, what else can you expect in 2022? LCD monitors with mini-LED full-array backlights are going to be more widely available. As we've already implied, mini-LED full array backlighting is never going to be as good as a true per-pixel technology like OLED for controlling light output. But done right it can give impressive results when it comes to contrast. Mini-LED is also capable of greater brightness than current OLED tech and gives better bright-scene HDR performance than an OLED panel.

BRIGHT AND BEAUTIFUL

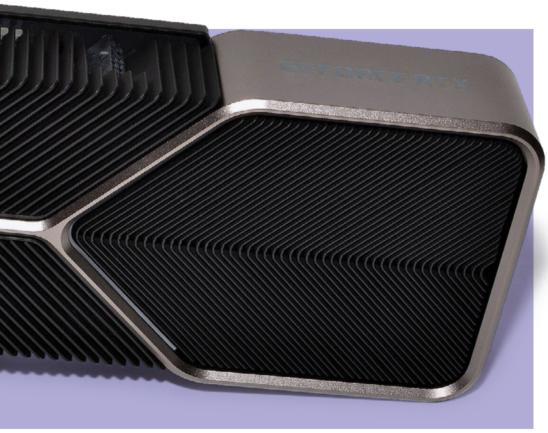
The brightest backlit LCD TVs, for instance, can hit nearly 2,000 nits of full-screen, eye-popping zing, whereas even the latest generation of OLED technology can only manage around 1,000 nits in small, isolated windows. In practice, absolute full-screen brightness isn't hugely relevant. But in brighter scenes, it really matters for HDR performance.

That's because the way that HDR content is mastered takes into account the limitations of human vision. The process is known as PQ or Perceptual Quantisation and it's based on a granular model of the human eye's ability to perceive two different levels of light. It's all rather technical, but the bit you need to know is that when a display cannot achieve the brightness anticipated when the content was mastered, details in bright areas bloom out or bleed into one another.

The result is a loss of detail. A good example involves clouds in a bright sky. On an OLED panel they tend to bleed into a featureless white mass, with the finer elements lost as large areas flatten out, whereas, on the best LED-backlit LCD screens, you can see lots of fine, wispy detail and features.

Anyway, in this category of mini-LED monitors that promise outstanding

techradar.



Only the latest graphics cards, including the Nvidia GeForce RTX 3080, can do 4K at 120Hz over HDMI.

HDR performance, the AOC AG344UXM and ViewSonic XG341C-2K should be interesting for gamers. Both are IPS monitors due this year and have the same basic form as the Alienware AW3423DW OLED panel. So that's 34-inch ultrawide and 3,440 by 1,440 pixels. The AOC will be good for 170Hz, while the Viewsonic will crank out 200Hz.

Both have mini-LED backlights with 1,152 zones and so should be able to deliver a true 1000-nit HDR experience rather than the pseudo-HDR that comes with DisplayHDR 400 panels only capable of 400 nits of brightness and which typically lack local dimming of any kind, let alone hundreds of mini-LED zones.

The Samsung Neo G8 looks pretty hot, too. Due any day now, it's a 32-inch 4K model with a 1,196-zone mini-LED backlight that's good for a whopping 240Hz. If that's likely to be pretty pricey, the likes of the Acer Predator X27S and Cooler Master GP27-FQS should be more attainable. Both are 27-inch 1440p models running at 160Hz powered by 576-zone mini-LED backlights. Overall, expect plenty more mini-LED monitors this year and hopefully at ever-lower prices.

If you're getting the sense that higher refresh rates are becoming the norm, that's going to be even more true as 2022 progresses. How much ever higher refresh matters for most gamers once you get beyond, say, 240Hz is open to question. But multiple 360Hz monitors are already available with 480Hz incoming, quite possibly by the end of 2022. Both LG and AU Optronics are close to releasing 480Hz IPS panels to monitor manufacturers. They're both expected to be 1080p 24-inch models, aimed at serious eSports addicts and pro gamers. Of broader interest, LG is working on a 1440p panel with a refresh rate beyond 240Hz. That should be out this year and sounds pretty sweet on paper.

Beyond all that, there will inevitably be detailed further improvements to existing LCD panel tech. LG debuted its so-called IPS Black high contrast technology in the Dell U3223QE earlier this year, which we reviewed recently (see our May 2022 issue). While it disappointed on first viewing, here's hoping future implementations improve. The one thing IPS tech could do with is a contrast boost and better native black tone rendering.

LG is also working on further improving both the pixel response and color accuracy of its IPS panels, including exceeding 100 percent of the DCI-P3 digital cinema space, which will be impressive if it happens. In terms of response, LG is planning on reducing the overshoot and inverse ghosting that results from heavily overdriven pixels, which in turn should improve the usable response time. LG hasn't divulged any specifics, but we'd estimate it will release its first 0.5ms GTG, rather than the even more forgiving MPRT metric, IPS panels. Here's hoping.

Still, if you add up all of the possible developments for conventional LCD tech in 2022, you arrive at a pretty spectacular overall solution, even without OLED becoming more widely available. If 2022 won't quite be the year of cheap OLED monitors for all, it is shaping up to be a good time to buy a new PC monitor.

The home of technology

techradar.com

EXPLORE THE BEST LINUX & OPEN SOURCE SOFTWARE

From the best distros to system security, utilities and fun applications, we've rounded up everything you could ever need

Linux & Open Source Annual 2022
Everything you need to master open source software and operating systems
180 pages of expert tips & tricks
Linux & Open Source Annual Volume Seven
100% UNOFFICIAL
ISBN 978-1-80023-779-7
FUTURE
VOLUME SEVEN

ON SALE NOW

FUTURE

Ordering is easy. Go online at:

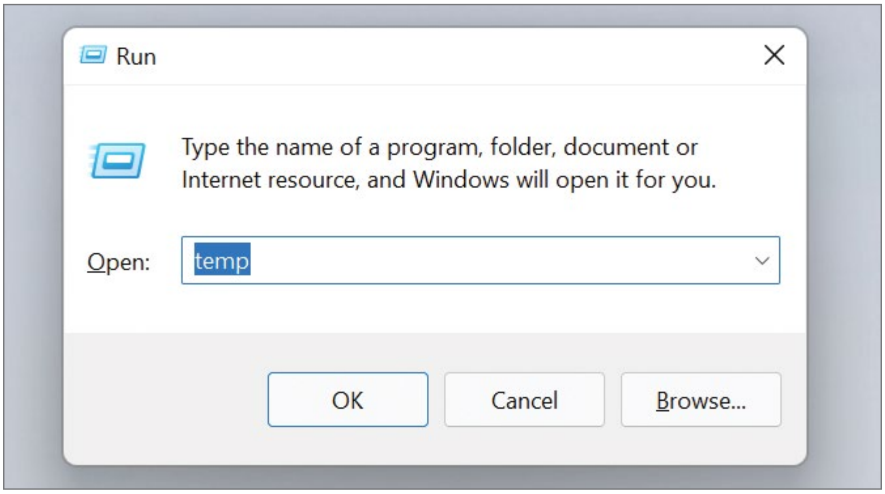
magazinesdirect.com

Or get it from selected supermarkets & newsagents

HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH



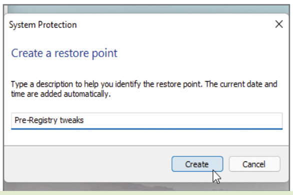
Type the name of a program, folder, document or Internet resource, and Windows will open it for you.

Open: temp

TEMPORARY FILE DELETE

If it feels as though your PC is getting a little sluggish, clearing temporary files can help to make things run faster and smoother. Press 'Windows + R' to open up the run application, then search 'temp' and then hit OK. This will open up a load of temporary files, most of which will be unnecessary. To clear all of these files, press 'CTRL + A' and then hit delete. Hopefully, this will help speed your computer up a little.

MAKE – USE – CREATE


System Protection

Create a restore point

Type a description to help you identify the restore point. The current date and time are added automatically.

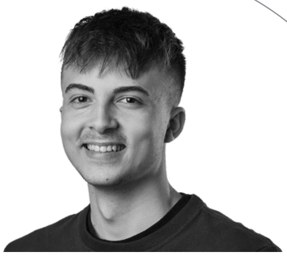
Pre-Registry tweaks

58
Get the most out of the Registry Editor in Windows 11.

62
Japan's 1980s home computer, the NEC PC-9800.

66
Build It, using one manufacturer's components only.

© MICROSOFT, WIKIMEDIA



SAM LEWIS
STAFF WRITER

INTEL'S NUC 12 MINI PC

With Intel's latest NUC 12 Extreme Dragon Canyon gaming Mini PC in my possession, you can bet your bottom dollar that it's found its way into my living room—at the expense of my Wii console. The Intel NUC 12 is so compact it sits and hides neatly under my TV unit, and with the RGBs turned off, it's actually a discreet little monster.

I've also been testing SCUF's Instinct Pro, so I essentially have a console-killer combo that I can use in the evenings. I'm not too thrilled about having to return the NUC back to Intel—the performance is just so impressive. Though I do feel guilty that I'm not pushing it to its absolute limits when playing older titles, I'm having a blast.

As sad as I'll be when the NUC has to go back, I'll be plugging the Wii straight back in as we have found our old *Guitar Hero* gear. It's kind of sad that we don't get games like these anymore. Who remembers the *Buzz* controllers on the PS2? These party titles were so much fun when your pals came round and you'd gather round the TV, but now everything is all online. I'm not trying to sound like an old man who's angry at modern life, I just miss that era of social gaming. So, while I'll be rocking along to *Guitar Hero World Tour* in no time, I bet I'll be rustier than an old trombone.

↘ submit your How To project idea to: editor@maximumpc.com

Advanced Windows 11 tips: Registry Editor

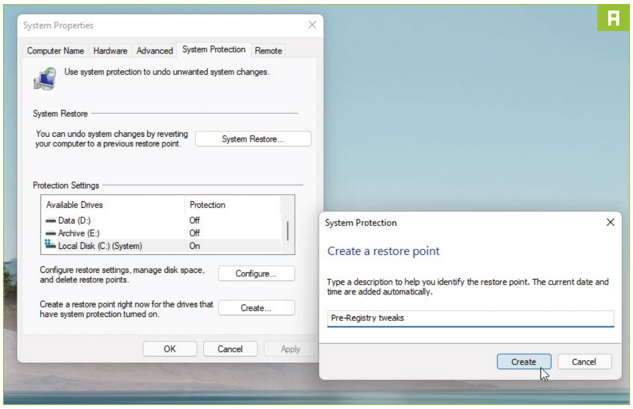
YOU'LL NEED THIS

WINDOWS 11
plus a Registry backup—use System Restore or a drive image tool. Optional extra: third-party Registry editor, such as O&O Registry Editor.

IF YOU'RE LOOKING TO GET MORE from your Windows 11 setup, you've come to the right place. In this issue, we'll take a deep dive into your Windows Registry, which has been a vital component of Windows since the days of Windows 95. Basically, it's a glorified database stored across several files (known as 'hives') containing various configuration settings that cover all aspects of your PC: its hardware, the apps you've installed, and—of course—Windows itself.

To simplify matters, most Registry changes can be made via other Windows tools such as Settings or Device Manager, or within an application's own dialog boxes. However, other settings are hidden more deeply. Many Windows tweaking tools such as Ultimate Windows Tweaker (www.thewindowsclub.com) offer an easy way to make meaningful Registry changes without risk but doing so means you never understand what's going on beneath the hood.

At some point, you'll need to access the Registry directly, whether it's to change an annoying feature or fix a problem, and that's where this tutorial comes in. We'll take you on a crash course of the Registry—how it works and how to edit it, plus reveal some useful tweaks that can make your Windows experience that bit better. **–NICK PEERS**



Use system protection to undo unwanted system changes.

You can undo system changes by reverting your computer to a previous restore point.

Available Drives	Protection
Data (D:)	Off
Archive (E:)	Off
Local Disk (C:) (System)	On

Configure restore settings, manage disk space, and delete restore points.

Create a restore point right now for the drives that have system protection turned on.

Create a restore point

Type a description to help you identify the restore point. The current date and time are added automatically.

Pre-Registry tweaks

1 START WITH A BACKUP

Before you start making wholesale changes to the Registry, make sure you have a fallback. It's technically possible to bring down your entire Windows installation from a botched Registry setting, although in most cases, you'll merely break a specific part of your system or the application you're trying to tweak. While you can undo most Registry edits, it pays to have a failsafe in place—personal experience says you'll thank us later.

» Backups come in various shapes and sizes. If your drive image tool supports differential or, better still, incremental backups, then create your failsafe backup here. Macrium Reflect Free (www.macrium.com/reflectfree.aspx) supports the former.

» You can also take a System Restore point, which backs up the Registry in its current state as well as other system files. Type 'system restore' into the Search panel and click 'Create a restore point'. Check System Restore is enabled for your system drive (click Configure if not) and then click Create to make a manual restore point. Give it a suitably descriptive name such as 'Pre-Registry tweaks' and click Create again [**Image A**].

» If you run into problems, either roll back your drive image or return to the 'Create a Restore point' dialog and click System Restore... to undo your changes. In the unlikely event Windows won't boot, wait until it brings up the recovery screen, then choose Troubleshoot followed by Advanced and System Restore.

2 ACCESS AND NAVIGATE THE REGISTRY

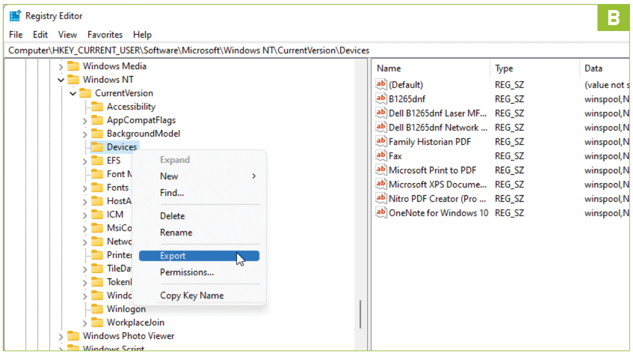
Windows offers its own built-in tool for accessing the Registry: Registry Editor (regedit.exe). It has all the tools you need to view and edit the Registry, although check the box over the page for a third-party alternative that makes Registry editing even simpler.

» The fastest way to access Registry Editor is to press Win + R, type regedit and press Enter. Administrative access is required, so click Yes when prompted. You'll see a two-paned window appear — the annotation reveals the key components of regedit's user interface.

» Registry Editor stores data as a series of values, organized into keys and subkeys as revealed in the Registry 101 box. To navigate, use the left-hand navigation pane like you would File Explorer: click a key to select it, or double-click a key to expand it and reveal any subkeys inside.

» Select a key or subkey and you'll see a list of its associated values appear in the right-hand pane. You can edit or delete existing values and keys—be careful, as deleting a key destroys all its values too—or create new ones from scratch.

» Given how easy this is to do, let's explore one final backup option: Registry Editor itself. Regedit allows you to export individual keys (and their values) as text-based .REG files—simply right-click the target key or subkey

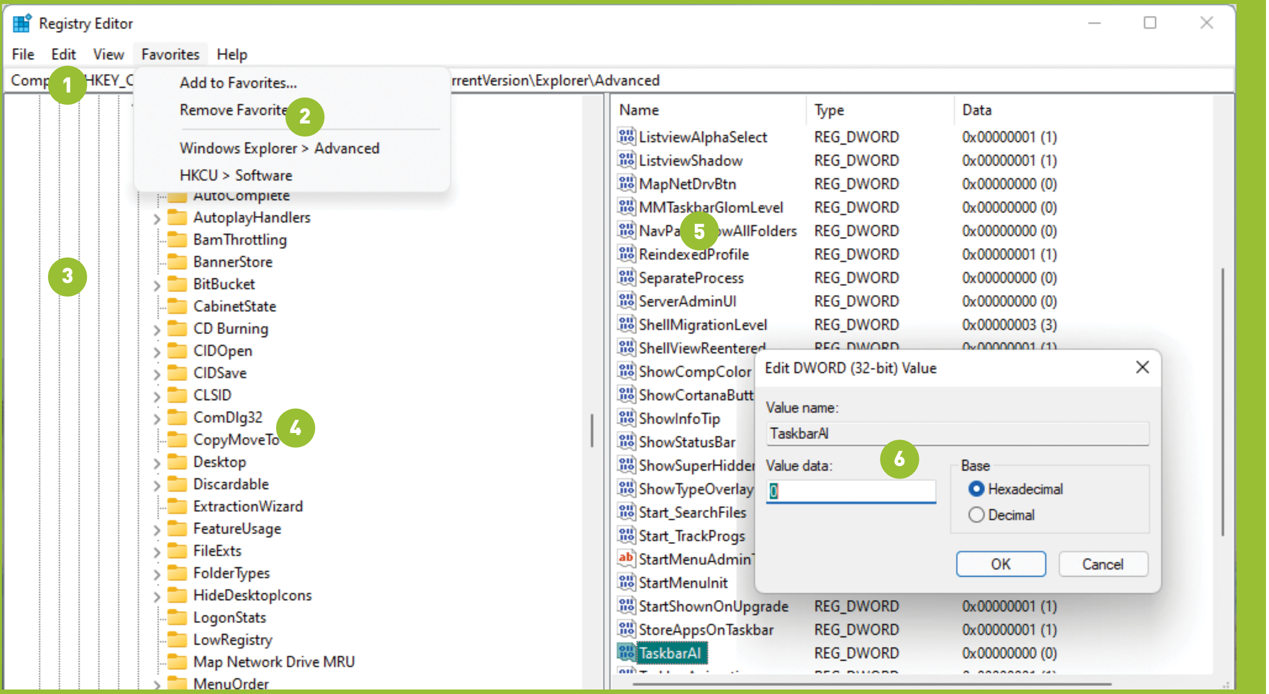


Computer\HKEY_CURRENT_USER\Software\Microsoft\Windows NT\CurrentVersion\Devices

Name	Type	Data
(Default)	REG_SZ	(value not s
B1265dnf	REG_SZ	winspool,N
Dell B1265dnf Laser MF...	REG_SZ	winspool,N
Dell B1265dnf Network ...	REG_SZ	winspool,N
Family Historian PDF	REG_SZ	winspool,N
Fax	REG_SZ	winspool,N
Microsoft Print to PDF	REG_SZ	winspool,N
Microsoft XPS Docume...	REG_SZ	winspool,N
Nitro PDF Creator (Pro ...	REG_SZ	winspool,N
OneNote for Windows 10	REG_SZ	winspool,N

© MICROSOFT

TOUR REGISTRY EDITOR


Registry Editor
File
Edit
View
Favorites
Help
Comp
HKEY_C
rrentVersion\Explorer\Advanced
Add to Favorites...
Remove Favorite
Windows Explorer > Advanced
HKCU > Software
AutoComplete
AutoplayHandlers
BamThrottling
BannerStore
BitBucket
CabinetState
CD Burning
CIDOpen
CIDSave
CLSID
ComDlg32
CopyMoveTo
Desktop
Discardable
ExtractionWizard
FeatureUsage
FileExts
FolderTypes
HideDesktopIcons
LogonStats
LowRegistry
Map Network Drive MRU
MenuOrder
1
2
3
4
5
6

Name	Type	Data
ListviewAlphaSelect	REG_DWORD	0x00000001 (1)
ListviewShadow	REG_DWORD	0x00000001 (1)
MapNetDrvBtn	REG_DWORD	0x00000000 (0)
MMTaskbarGlomLevel	REG_DWORD	0x00000000 (0)
NavPa wAllFolders	REG_DWORD	0x00000000 (0)
ReindexedProfile	REG_DWORD	0x00000001 (1)
SeparateProcess	REG_DWORD	0x00000000 (0)
ServerAdminUI	REG_DWORD	0x00000000 (0)
ShellMigrationLevel	REG_DWORD	0x00000003 (3)
ShellViewReentered	REG_DWORD	0x00000001 (1)
ShowCompColor		
ShowCortanaButt		
ShowInfoTip		
ShowStatusBar		
ShowSuperHidde		
ShowTypeOverlay		
Start_SearchFiles		
Start_TrackProgs		
StartMenuAdmin		
StartMenuInit		
StartShownOnUpgrade	REG_DWORD	0x00000001 (1)
StoreAppsOnTaskbar	REG_DWORD	0x00000001 (1)
TaskbarAl	REG_DWORD	0x00000000 (0)

Edit DWORD (32-bit) Value

Value name: TaskbarAl

Value data: 0

Base: ● Hexadecimal ○ Decimal

OK Cancel

1. ADDRESS BAR
This recent addition to Registry Editor allows you to type or paste in Registry addresses to quickly jump to the specified subkey.

2. FAVORITES
Registry Editor allows you to store frequently accessed subkeys in its Favorites menu, giving you one-click access. Make sure you give them a suitably descriptive name.

3. NAVIGATION PANE
This left-hand pane allows you to move up and down through the various keys and subkeys that make up the Windows Registry.

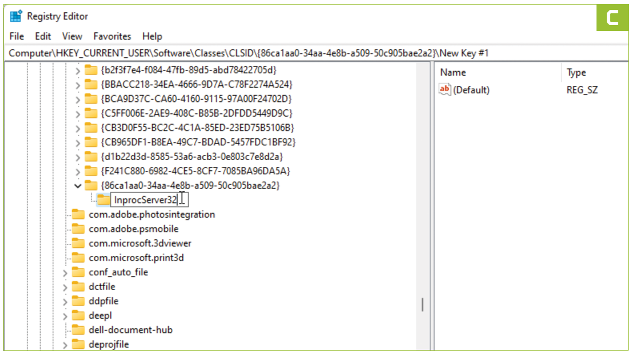
4. SUBKEYS
A key or subkey that has a → next to the folder signifies that it contains further subkeys inside. Double-click on the arrow icon to open the subkey and reveal its contents.

5. REGISTRY VALUES
Each subkey contains one or more values that are used to record preferences and other settings. Values can contain text or numbers depending on their type.

6. EDIT SCREEN
Double-click a value to edit it. String-based data contains a single editable field, while numerical values can be formatted in decimal or hexadecimal.

in the left-hand pane and choose Export [**Image B**]. Give your backup a suitable name (and save it to your backup drive) before clicking Save.

›› You can restore a backup via File → Import inside Registry Editor or by simply double-clicking the .REG file and clicking Yes twice when prompted. These settings will overwrite whatever is current in the Registry (including any changes you've made), restoring things to how they were.


Registry Editor
File
Edit
View
Favorites
Help
C
{b2f3f7e4-f084-47fb-89d5-abd78422705d}
{BBACC218-34EA-4666-9D7A-C78F2274A524}
{BCA9D37C-CA60-4160-9115-97A00F24702D}
{C5FF006E-2AE9-408C-B85B-2DFDD5449D9C}
{CB3D0F55-BC2C-4C1A-85ED-23ED75B5106B}
{CB965DF1-B8EA-49C7-BDAD-5457FDC1BF92}
{d1b22d3d-8585-53a6-acb3-0e803c7e8d2a}
{F241C880-6982-4CE5-8CF7-7085BA96DA5A}
{86ca1aa0-34aa-4e8b-a509-50c905bae2a2}
com.adobe.photosintegration
com.adobe.psmobile
com.microsoft.3dviewer
com.microsoft.print3d
conf_auto_file
dctfile
ddpfile
deepl
dell-document-hub
deprojfile

Computer\HKEY_CURRENT_USER\Software\Classes\CLSID\{86ca1aa0-34aa-4e8b-a509-50c905bae2a2}\New Key #1

InprocServer32

Name	Type
(Default)	REG_SZ

3 YOUR FIRST REGISTRY TWEAK

Let's start with a simple example of how you can change a Windows setting using the Registry. This first example merely requires you to create a single Registry value, then alter it. First, navigate to the following subkey in Registry Editor's left-hand pane: HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\Explorer\Advanced.

›› You'll see a host of values appear on the right, all of which refer to some aspect of the Windows user interface. Choose Edit → New → DWORD (32-bit) Value and name the new value TaskbarAl (that's a lowercase 'l' at the end, not a capital 'I').

›› As soon as the value is created, it will be assigned a value of 0, and you'll immediately see the taskbar icons align to the left as per previous versions of Windows. Double-click the value and change it to 1, and they will return to being centrally aligned.

4 REMOVE THE NEW CONTEXT MENU

Now for something more complicated. If you're fed up with having to click 'Show more options'

REGISTRY 101

The Registry consists of a series of files known as 'hives', stored in two separate locations: Windows → System32 → Config for system-wide settings, and your personal User folder for settings associated with your user account.

Each hive consists of a different set of preferences and configuration data—for example, system-wide software settings are stored in a file called SOFTWARE. This information is organized into sub-folders or 'keys'. Each key contains one or more 'values' with associated 'value data', which are the configuration settings for your PC.

There are numerous types of value, depending on the data they contain. The most common include REG_DWORD values, which contain binary or hexadecimal numbers in 32- bit format (the 64-bit equivalent is REG_QWORD), and REG_SZ, which contains text such as drive labels, context-menu options, or the path to a particular folder or file on your hard drive.

Whenever Windows, a program, or hardware device needs certain settings or information, it consults the Registry for the specific values it needs, enabling it to function correctly. These keys, subkeys, and values are usually added when the software or hardware is first installed, and organized in a logical, accessible manner—for example, the HKEY_CURRENT_USER\SOFTWARE subkey contains many Windows and application settings.

whenever you right-click an item in File Explorer to bring up the classic context menu, you can disable this new, dumbed-down menu using the Registry.

» First, navigate to the following key: HKEY_CURRENT_USER\Software\Classes\CLSID. Now right-click the CLSID subkey and choose New → Key from the pop-up context menu. Now comes the tricky bit, you need to rename this key to the following:

`{86ca1aa0-34aa-4e8b-a509-50c905bae2a2}`

» Once done, select this newly created subkey, right-click it and choose New → Key again. Name this new subkey InprocServer32 [**Image C**] and then with InprocServer32 selected, double-click the solitary (Default) value in the right-hand pane. Simply click OK and its data will change from (value not set) to blank, which is enough to trigger the tweak.

» Our previous Registry tweak was applied instantly, but others only come into effect when you restart Windows Explorer or, in some cases, your entire PC. The context menu tweak requires you to restart Windows Explorer, which is done via Task Manager: select Windows Explorer on the Processes tab (if it's not under Apps, you'll find it under Windows processes) and click the Restart button.

» Once done, open a File Explorer window and right-click an item, you should now see the classic menu pops up immediately. To undo this tweak, simply delete the {86ca1aa0-34aa-4e8b-a509-50c905bae2a2} key you created, then restart Explorer again.

5 GO DIRECT TO A SPECIFIC KEY

Navigating the Registry can be a time-consuming process as you move between keys, subkeys, and values. A recent addition to Registry Editor is the Address Bar, which works in a similar way to the folder path bar in File Explorer or the URL bar in your web browser. This allows you to jump directly to a specific subkey by typing in the address manually – for example: HKEY_LOCAL_MACHINE\SOFTWARE\Policies\Microsoft\Windows.

» Don't worry about including the 'Computer\' bit, Registry Editor knows to add this. It's still quite a complex process, but thankfully you can use shortcuts in place of the lengthy HKEY_ part of the address: for example, use HKCU for HKEY_CURRENT_USER and HKLM for HKEY_LOCAL_MACHINE.

» Even better, the Registry's Address bar supports copy and paste from other sources, so you can paste in full Registry addresses from text documents, websites, or wherever you happen to find them.

6 MAKE USE OF FAVORITES

Another way to speed up access to frequently accessed sub-keys is to use Regedit's Favorites feature. Select the key you want to access and choose Favorites → Add to Favorites. By default, the sub-key name is given as its entry, you can tweak this to make it easier to identify and click OK. In future, jump back to the key by selecting it from the Favorites menu [**Image D**].

» There are more useful shortcuts when navigating Registry Editor. Open a key containing dozens of sub-keys and you can quickly jump to one of these by typing the first two or three letters of its name. You can also use the cursor keys to navigate around the Registry, using the left arrow to collapse previously opened sub-keys.

7 TIME-SAVING TWEAKS

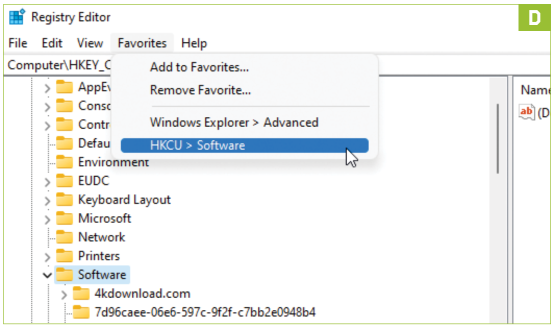
Other tweaks involve adding features to make options more accessible or removing unwanted steps in processes to speed things up. Let's start by speeding up application switching using the taskbar.

» If an app has more than two windows open, you'll be forced to select your chosen window after clicking the app's taskbar icon, but you can save a click and simply restore the last active window, by navigating to HKCU\Software\Microsoft\Windows\CurrentVersion\Explorer\Advanced.

» Make sure Advanced is selected and choose Edit → New → DWORD (32-bit) Value. Name this LastActiveClick, then double-click it and change its value to 1. After restarting the Windows Explorer process, you should find clicking the program's taskbar icon always takes you back to the last window you'd opened.

» Adding custom entries to the File Explorer context menu allows you to copy or move selected files to a specific folder from a single dialog. First, navigate to HKCR\AllFilesystemObjects\shellex\ContextMenuHandlers. Create a subkey inside this called Copy to Folder, then double-click its (Default) value and set it to {C2FBB630-2971-11D1-A18C-00C04FD75D13} before clicking OK.

» Next, create a second subkey inside ContextMenuHandlers but this time, name it Move to



©MICROSOFT

Folder and change its (Default) value to {C2FBB631-2971-11D1-A18C-00C04FD75D13}—note the subtle difference between the two values. The change is immediate, and you'll find both options on the classic context menu (the one that appears when you select 'Show more options' if you haven't performed the tweak from step 4).

8 MAKE CHANGES WITH BATCH SCRIPTS

Why get your hands messy with Registry Editor when you can make changes to the Registry directly from Notepad? By creating special script files using any text editor, then saving them with a .reg file extension you then simply double-click the .reg file to merge your changes into the Registry.

» To do this, open a blank document in Notepad. Now type the following line at the top:

```
Windows Registry Editor Version 5.00
```

» This identifies the script as a Registry file. Add a blank line beneath this, then type below that:

```
[Regpath]
```

» Keep the square brackets but replace Regpath with the Registry key you wish to edit (any sub-keys that don't already exist will be automatically created, so you don't need manually create them in regedit first). Beneath this, type each of the values you wish to create or modify on separate lines using the following syntax:

```
"ValueName"=Valuetype:Value
```

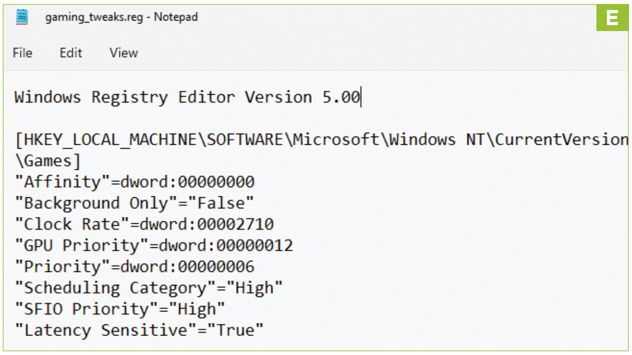
» Valuetype should be ignored if the value is a string; otherwise, enter 'binary' for hexadecimal values, 'dword' for dword values. The example [**Image E**] creates a system profile you can apply when gaming to squeeze more performance out of your PC.

» You can edit multiple Registry keys within a single document. Leave a blank line between each [Regpath] entry. Once done, choose File → Save, change 'Save as type:' to 'All Files' and remember to save your file with a .reg extension. Then back up and double-click the file to merge it into the Registry, or right-click and choose Edit to make further changes in the text editor.

9 WHO NEEDS GPEDIT.MSC?

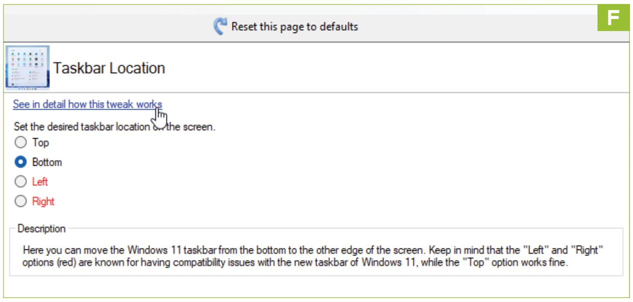
When surfing the net for useful tweaks—particularly when it comes to securing your PC—you'll often find a reference to gpedit.msc, or Group Policy Editor. This tool makes it easy to set various security and privacy policies in Windows, and while it's aimed at enterprise and business users, it's often handy for us mere mortals too.

» The only problem with gpedit.msc is that it's not available in Home editions of Windows. But don't worry, because Group Policy Editor is basically a neat front end for various Registry settings—it doesn't apply them directly, but they're eventually translated via special "local policy" files that are applied after a reboot. All you need to know is which tweak applies to which Registry setting, and thanks to a handy Excel file from Microsoft, you can do just that—download the Windows 11 21H2 ADMX spreadsheet.xlsx file from www.microsoft.com/en-us/download/details.aspx?id=103506 for the translation you need.


E

```
Windows Registry Editor Version 5.00

[HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows NT\CurrentVersion
\Games]
"Affinity"=dword:00000000
"Background Only"="False"
"Clock Rate"=dword:00002710
"GPU Priority"=dword:00000012
"Priority"=dword:00000006
"Scheduling Category"="High"
"SFIO Priority"="High"
"Latency Sensitive"="True"
```


F

Reset this page to defaults
Taskbar Location
See in detail how this tweak works

Set the desired taskbar location on the screen.

○ Top
● Bottom
○ Left
○ Right

Description

Here you can move the Windows 11 taskbar from the bottom to the other edge of the screen. Keep in mind that the "Left" and "Right" options (red) are known for having compatibility issues with the new taskbar of Windows 11, while the "Top" option works fine.

10 GET MORE TWEAKS

The internet is awash with Registry tweaks for you to try out, just make sure that you trust the website in question and have taken a recent backup before you begin.

» Start your search with SpeedGuide's Gaming Tweaks (www.speedguide.net/articles/gaming-tweaks-5812). Tweaks from older versions of Windows should work in many cases, particularly those for Windows 10, but it's worth Googling the tweak in question with "Windows 11" to see if there are known compatibility issues.

» As we stated, most tweak tools for your PC basically provide you with a user-friendly front end to tweak various Registry settings. One such tool, Winaero Tweaker (https://winaero.com/winaero-apps/), goes further than most in allowing you to understand what exactly it is the tweak in question does.

» When selected, click 'See in detail how this tweak works' [**Image F**] and you'll be whisked to a page detailing what the tweak does and, if applicable, what Registry settings are changed. ⏻

REGEDIT ALTERNATIVES

If you plan to spend time tweaking Registry keys, you may become frustrated at some of Registry Editor's drawbacks. Spying an opportunity to fill those missing gaps, several third-party Registry editing tools have emerged.

One of the highest-rated is O&O RegEditor (www.oo-software.com/en/ooregeditor), a freeware portable editor. Download the 1MB zip file and extract its contents, then double-click OORegEdt.exe to launch it. You'll be prompted to make the app the default for opening .REG files—click 'No' for now until you're sure it's right for you.

You will see a summary of extra features O&O RegEditor offers: the Address bar keeps a history of previously visited subkeys for easy access, while the Favorites menu also makes a note of frequently used keys alongside any you create yourself (you can also import and export Favorites, unlike with Registry Editor).

In addition, the Search tool narrows your search to the currently selected key or subkey and lays out the results in a more logical way. O&O RegEditor also enables you to copy and move entire keys (sometimes, you'll need to duplicate keys between two locations, typically HKLM and HKCU).

Machine of the Month: NEC PC-9800 (1982)

YOU'LL NEED THIS

A COPY OF THE NEKO PROJECT
http://nenecchi.kirara.st/

THIS MONTH'S COMPUTER may be unfamiliar, but NEC's PC-9800 series, usually shortened to PC-98, was arguably Japan's most important computer and played an integral part in developing both Japanese language computing and video games. Despite the potential gaming fun offered by this system, there are technical hurdles to be overcome. So after a brief history of the PC-98, let us show you how to emulate the machine as easily as possible. –**JOHN KNIGHT**

1 DEVELOPMENT AND LAUNCH

The PC-98 was a strategically brilliant move by NEC, beating Western competition by exploiting their inept support for Kanji: the complex characters inherited from Chinese, used in any formal writing. NEC recognized the limitations of Western rivals and designed its machine from the ground up to provide solid Kanji rendering and input.

» NEC based its new computer around Intel's 8086 processor, but don't be fooled—even though these machines are powered by x86 CPUs (and can run modified versions of DOS and Windows), these are not "IBM-Compatible" PCs. This is a proprietary platform with a different BIOS, I/O ports, graphical system, expansion slots, and even different floppy drives.

» NEC wanted its computer to run Microsoft BASIC and be code-compatible with the N88-BASIC of its previous PC-88 line. However, NEC was unable to reach a deal with Microsoft, and simply reverse-engineered N88-BASIC, re-writing it to work on x86 processors.

» The first model, the PC-9801, launched in October 1982, for ¥298,000 (worth around $1,200 then). Its 8086 CPU ran at 5MHz and came with a base 128KB of RAM, expandable to 640KB.

» While IBM PCs were still lumbered with four-color CGA, NEC's μPD7220 twin video chips ran at a much higher 640x400 resolution, with eight colors. However, like IBM PCs, the sound was basic, with only a simple beeper.

» For storage, customers were offered 8-inch 1.232MB external floppy drives, though 320KB 5.25-inch models followed.

2 SOFTWARE

The PC-98 was designed to be a work machine and doesn't feature the kind of sprite or blitter processing that action games demanded. The most popular applications were word processors, and the platform also received ports of serious business operating systems, such as CP/M-86, OS/2, and Unix variant PC-UX. Nevertheless, despite its all-business intent, its market share ensured the PC-9800 had a thriving game scene.

» Its high-resolution graphics spawned countless interactive graphical novels, dating simulations, and huge amounts of Hentai (cartoon pornography). These games usually featured a point-and-click adventure-style interface, with high-resolution images and occasional animations.

» The machine's extra clock speed and memory also made it a great platform for simulators, like *Air Management* (1992), and strategy role-playing games, such as the Sangokushi series and Brandish games. The machine also had its share of "bullet-hell" shoot-'em-up titles, such as the famously bizarre Touhou series!

» Of course, the main issue is finding games that don't require a working knowledge of Japanese. You can guess your way around simple arcade titles, like the shoot-'em-up *Rude Breaker* (1996). Plus, there were ports of Western games that had an English language option, such as *AD&D: Dragon Strike* (1992), *Sim City* (1990), *Wizardry 3* (1987), and *The Bard's Tale* (1988).

» However, there is now a much better source for English speakers (see the box).

3 LEGACY

Although the PC-98 never sold outside of Japan, NEC's computer dominated sales in its home territory, with a market share of between 60-70 percent.

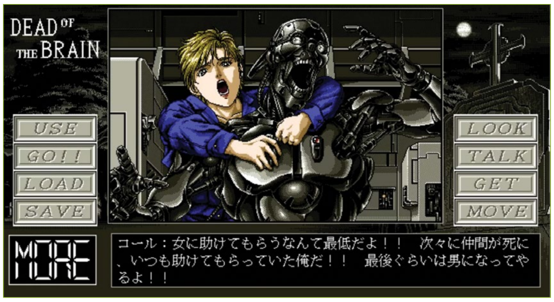
» As the x86 architecture continued to develop and evolve, the PC-98 platform evolved with it. Each new generation of Intel processor would bring new PC-98 models. Some machines had Intel CPUs, some had NEC's "V" clone CPUs, and some even had both.

» Although the original machine had only simple beeper audio, proper sound cards soon followed. The main sound chip of note is the Yamaha 2203, or "OPN". This chip was quite basic but predated cards like the Sound Blaster or AdLib, and still has fans today.

» Data storage was quick to upgrade. Customers soon had the option of 640KB Double Density 5.25-inch drives or 1.232MB High-Density 3.5-inch models. The PC-98's SCSI hard disk interface was much faster than most PCs and was easy to install due to the machine's special C-Bus expansion system.

» Over time, the PC-98 series grew closer to IBM's standard and its software library. The factory-installed OS moved away from NEC's BASIC to ported versions of MS-DOS and Windows. Later machines were updated to VGA standard with 256 colors and a 640x480 resolution.

» The PC-98 eventually began losing sales to cheaper machines running IBM Japan's DOS/V: a DOS variant capable of rendering Kanji through standard VGA.



コール：女に助けてもらうなんて最低だよ！！　次々に仲間が死に、いつも助けてもらっていた俺だ！！　最後ぐらいは男になってやるよ！！

» **The PC-98 established Japan's interactive novel style. The thick borders and distinctive font are still used today.**

© WIKIPEDIA

» During the 1980s and 90s, if a Japanese person said 'PC', they usually meant one of these, not an IBM-Compatible.

» However, the PC-98's reign was ultimately brought to an end by Windows 95. Although NEC supported the system, IBM-Compatibles now had proper Japanese support and provided the same essential functionality for a lower price, with much better backward compatibility.

» By 1997, the "PC-98" line had devolved into straight IBM-Compatibles, which is where we'll call the PC-98's end. The final machine with a PC-98 badge was released in 2000 with a 433MHz Celeron CPU before the name was discontinued in 2003. By the end of its reign, the PC-98 series had sold over 18 million units.

4 EMULATION

There are a couple of choices of emulator, but the Neko Project is the most used. Linux users can try old packages of the native port "XNP2", but the main Windows version is more up to date and runs well through Wine.

» To download the Neko Project, go to the project homepage at nenecchi.kirara.st. The website is in Japanese but simply click on the link "np2fmgen.7z" under the PC-98 heading, which will download the emulator.

» Extract the package and open the new folder. There will be a collection of executable files: they all basically work and function the same, but emulate different machines—anything with an "sx" in the filename will emulate a machine with an SX processor. We recommend starting with np21nt.exe, but if something doesn't load under one program, try another.

SPECIFICATIONS

NEC PC-9800 SERIES (1982)

CPU:	Intel 8086 @ 5MHz
VRAM:	12KB & 256 KB
RAM:	128KB, upgradeable to 640KB
Launch price:	¥298,000 (approx. $1,200)
Graphics:	2 x NEC µPD7220 graphical controllers, 8 colors @ 640x400
Sound:	PC speaker
Storage:	8-inch, 1.232MB external floppy drives
OS:	N88-BASIC(86), CP/M-86, MS-DOS, OS/2, PC-UX, Microsoft Windows up to Windows 2000
Released:	October 1982
Production:	1982-1997, 2003
Worldwide sales:	18.3 million

ENGLISH TRANSLATIONS

To avoid spending valuable gaming time using Google Translate, some cool internet folks are making English patches for PC-98 games. Two teams are particularly active: 46 OkuMen at 46.okumen.com and Nebulous Translations at nebulous.group.

They have an impressive list of titles, including *Brandish 2* (1995); cult JRPG favorite, *E.V.O: The Theory of Evolution* (1990); *Castlevania* clone *Rusty* (1993); and strategy mech game, *CRW: Metal Jacket* (1994). The two biggest games are *Dead of the Brain* (1992), a zombie-apocalypse adventure title; and Konami's cyberpunk thriller, *Policenauts* (1994).

5 LOADING PROGRAMS

To load a floppy image, the most common format, from the main menu, choose FDD1 → Open, then select your floppy image and click Open.

» Many floppy images are in .fdd format, which Neko's file browser won't recognize. When browsing, change your file type from "All Supported Files" to "All Files".

» Once your floppy image has been chosen, reset the emulator by clicking Emulate → Reset. Most software should automatically boot.

» If your program needs mouse input, middle-click to toggle the capture of mouse input. Alt + Enter will toggle full-screen mode.

» There is a chance your games will require 'disk swapping', so remember, there are two floppy menus, FDD1 and FDD2, and an Eject button under each menu.

» If you want to try hard disk images, you may have to learn your way around DOS. The "Harddisk" menu is divided into IDE and SCSI menus. IDE hard drive images can be in .hdi, .thd, or .nhd formats. SCSI hard disk images must be in Virtual98 .hdd format.

» Remember to reset the emulator once your hard disk image is selected.

6 FIXING FONTS

When you first load Neko Project, the Japanese text will be garbled nonsense. To experience this computer properly, you need a Japanese font.

» Head to https://46okumen.com/pc-98-emulation, to find English patches plus an excellent tutorial for taking Neko Project further.

» Download the font file, called FONT.ROM, then from the main menu, click Emulate → Font, and open the font file. When you click Emulate → Reset, any Japanese text should now display properly.

» *Policenauts* (1994) was a stunning technical achievement, showcasing its moody settings and excellent soundtracks.

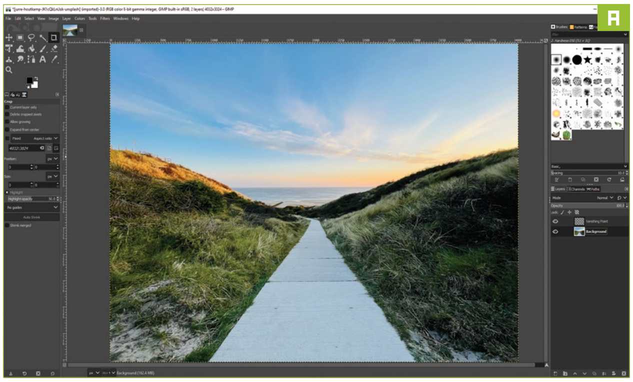
GIMP 3D perspective

YOU'LL NEED THIS

GIMP 2.1
OS: Windows 7 or newer.

FOR THIS TUTORIAL, we ´ll be turning our attention to 3D image placement and how to bring two images together while maintaining the same 3D perspective. We'll be using GIMP for this tutorial and a royalty-free image by Jurre Houtkamp on Unsplash (unsplash.com) to show how to build your photo manipulation skills. Practicing using sites like Unsplash allows you to play around with high-quality images with plenty of manipulation potential. We'll also be using a flat graphic site called the Noun Project (thenounproject.com) for a flat sign we'll be adjusting.

This should build your knowledge of perspective and help you blend images together while maintaining a natural finish. We'll also be touching on textures, as we bring the texture from our original image into the graphics from The Noun Project. You can choose any image for this tutorial but to start, choose an image that's looking straight towards the horizon. **–SAM LEWIS**



1 CHOOSE YOUR IMAGE

As we mentioned above, we chose an image from Unsplash by Jurre Houtkamp, which is of a beach in the Netherlands. We'll be adding a beach graphic into the path on this image as if it has been painted on.

›› Once you've found an image you're happy with, open up GIMP, then go to File, Open and find your image. Alternatively, you could drag and drop the image into your workspace [**Image A**].

›› After the image has been placed, we're going to find our vanishing point, which is the core of the image's perspective. The vanishing point is where two parallel lines on an image eventually join up. To create this, first, make a new layer. From the default arrangement on GIMP, this is usually in the bottom right corner—the icon is of a piece of paper with a plus sign on it. Name this layer 'vanishing point' and rename your image layer to 'background layer'.

2 VANISHING TRICKS

Once that's prepared, we can start drawing our vanishing points. Making sure you're on your vanishing point layer, go to the tools on the left, and select the paintbrush tool. Make sure this is a small point size, nothing too specific. Then, click on the bottom left of the path in the image and hold the 'SHIFT' key. This will enable you to draw in straight line mode. With this straight line, follow the line of the path and continue it until it reaches the top of the page. Repeat this process on the right-hand side afterward [**Image B**].

›› Next, bring the top margin down for the horizontal line to hit where the two perspective lines meet and do the same for the side margin. You should now end up with something like we have in our image. The point where all the lines meet is the vanishing point.

3 ICONIC IMAGES

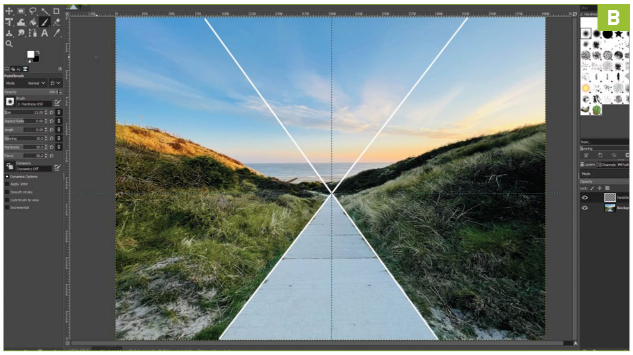
It's time to bring in our icon. We've opted for a sunset graphic and are aiming for this to look as though it has been painted onto the path. To bring this into our document, copy it from the website and then go to Edit → Paste As → New Layer. Then rename this layer.

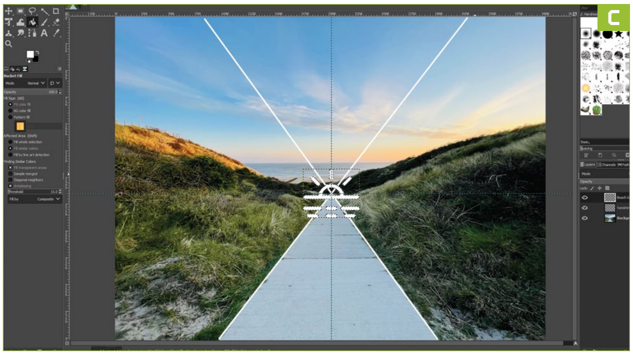
›› Head to the top again and go to Layer and then Crop to content. This cuts the layer down to the size of the graphic we've just pasted in. Then drag this to the vanishing point and it should snap into place. If it doesn't snap, head to the View drop-down and make sure that 'snap to grid' is selected [**Image C**].

4 MAGIC TRANSFORMATIONS

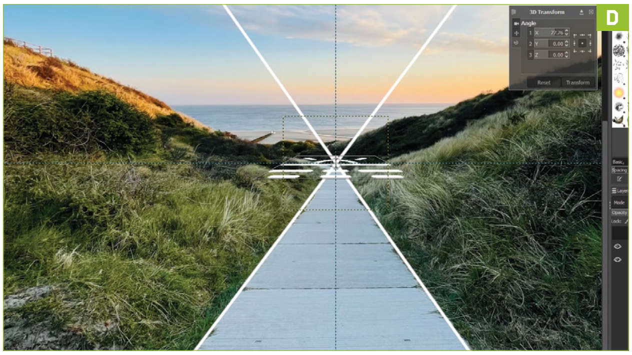
This is where the magic happens. We can hide the vanishing point layer for now as we have our icon in place. Then, while on the icon layer, hit 'SHIFT' + 'W' to bring up the 3D transform tool.

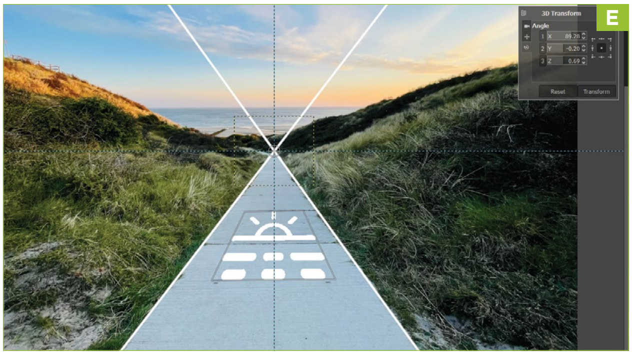
›› When this opens up, on the left-hand side, make sure under the 3D transform options that 'Unified interaction' is checked [**Image D**]. Then, hover your mouse over to the





© UNSPLASH BY JURRE HOUTKAMP, GIMP


D
3D Transform
Angle
1 X 77.76
2 Y 0.00
3 Z 0.00
Reset
Transform


E
3D Transform
Angle
1 X 89.20
2 Y -0.20
3 Z 0.69
Reset
Transform

side of the icon, and you can hold 'SHIFT' and tilt the image back and forth, giving it a 3D perspective.

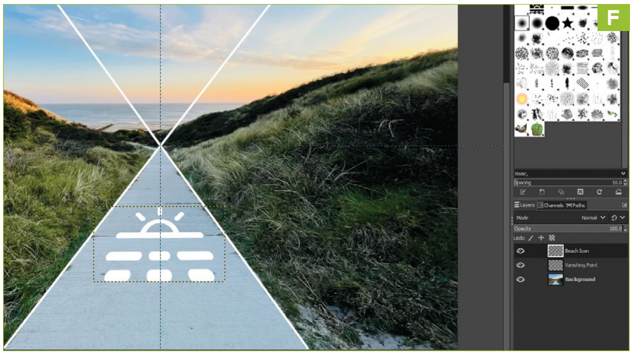
» Make the layer vanish by tilting it back into the horizon—it will appear as though it's a flat line, like in our image [**Image E**]. Once you hover your mouse over the flat line where the image is hidden, this will change to the move tool icon and then you can drag your image down and it will start to appear as in our example. Then, drag this down towards the path so it follows the perspective and sits nice and flush with the pathway.

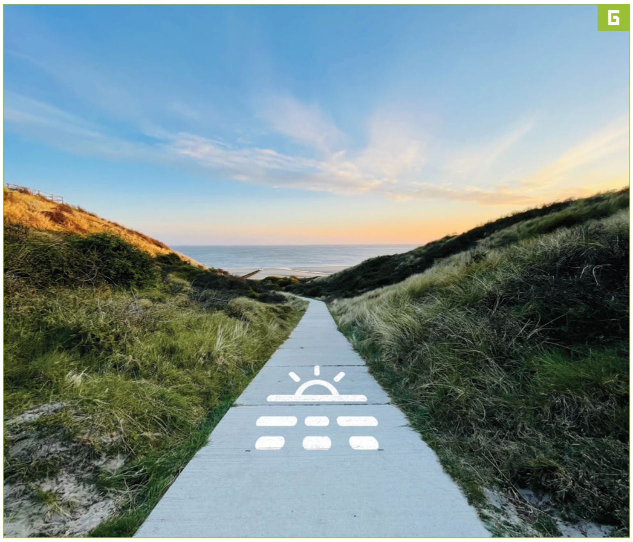
» To alter the size, once it's in position, hold the 'CTRL' key—this locks the Z-axis to make sure the perspective remains the same. Once you're happy with the position, hit 'transform' on the 3D transform pop-up window to confirm your selection.

5 ADDING TEXTURE

To finish the image off, we'll be adding the texture from the original onto our icon. Duplicate the original background and bring this layer to the top. Then change the blending mode to 'Grain merge'.

» Now, we'll create a layer mask from the icon layer, so click on this layer while holding down the 'ALT' key to create a selection from it. Then right-click on the top layer, hit 'add layer mask', and on the drop-down click the 'selection' option. Next, select the icon layer once more, go to 'layer' and select the option 'layer to image size' [**Image F**]. Then, hit the forward slash key to bring up the search, and once this is open type 'Bump Map and hit enter.

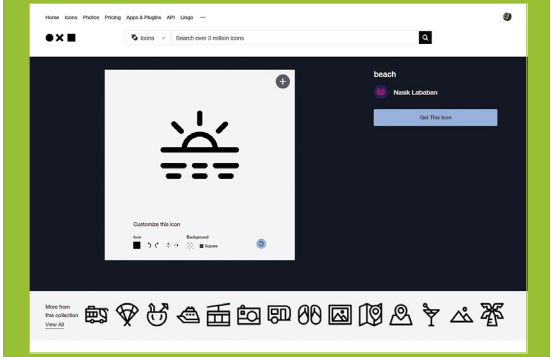

F
Basic,
Spacing
Layers
Channels
Paths
Mode
Normal
Opacity
100.0
Lock
Beach Icon
Vanishing Point
Background



» The Bump Map can transfer textures from one layer to another with fine adjustment. After the window pops up, click on the question mark and double-click the original background layer. Then you can tweak the elevation and depth sliders to get a 3D texture you like.

» Once you're happy, hit 'OK' and there you have it [**Image G**]. You've just created a painted graphic to an existing image using 3D perspective and a vanishing point. Keep trying this on various images with alternative shapes and images. These skills are great at helping you to understand how perspective works in an image. ⏻

NOUN PROJECT


Home
Icons
Photos
Pricing
Apps & Plugins
API
Lingo
●✕■
Icons
Search over 3 million icons
beach
Nasik Lababan
Get This Icon
Customize this icon
Icon
Background
Square
More from this collection
View All

Whether you're creating digital artwork or just practicing as a hobby, at some point you'll probably need preset icons to use in your work. If that's the case, visit the Noun Project's website (thenounproject.com), where you'll find a huge online library of flat graphics, icons and typographic symbols. Paid memberships give you full access, but the free service offers access to over 3 million icons that you can save in PNG and SVG formats. It's a great place to start looking.

BUILD IT

GUY COCKER, EDITOR-IN-CHIEF

MSI Special Single Manufacturer Build

Is using one manufacturer's components a good idea?

LENGTH OF TIME: **2-3 HOURS** | LEVEL OF DIFFICULTY: **EASY**

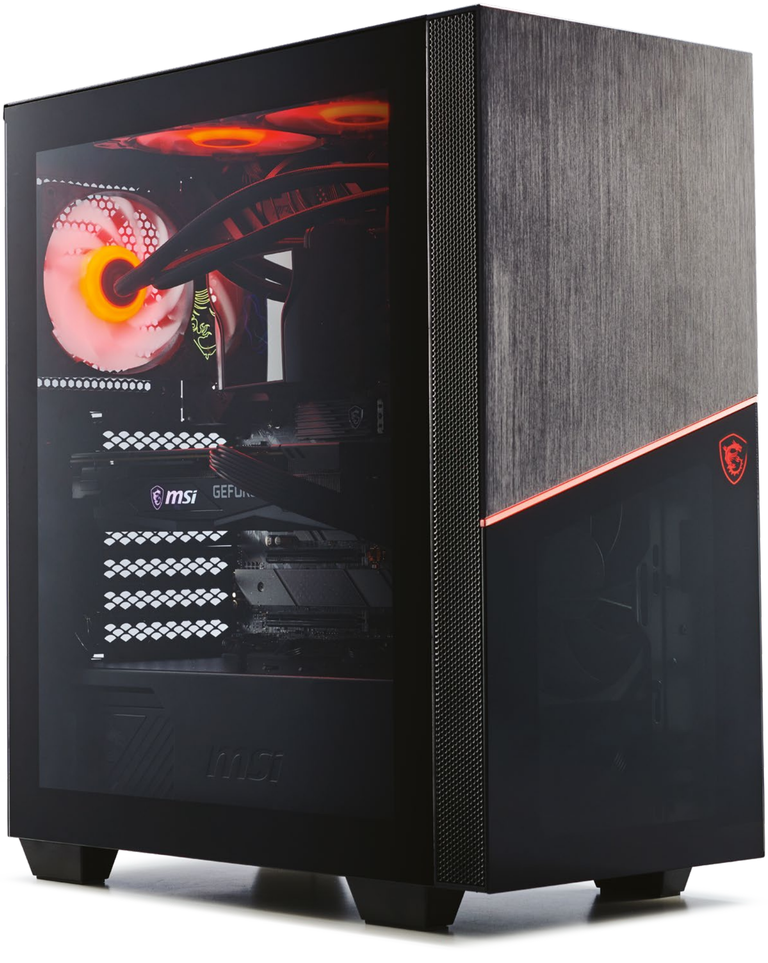
THE CONCEPT

IF YOU BUILT your desktop PC, it's probably a hodgepodge of different manufacturer components all working in tandem. That's the beauty of PC building—if you want to mix things up for price or performance reasons, common standards mean you can. But every manufacturer seems to have its own lighting standards and management app, and some use different styling or coloring that can mess with a uniform look. But what if you want to build a computer, while still recreating the feel of a pre-built system. What would that look like?

Thanks to the good people at MSI, we can find out this issue. During discussions about the company's 2022 components, including its first SSD drive, the Spatium M480, and the Sekira 100R case, we asked them: could we get everything into our labs at the same time and make a build out of it all? The company obliged, sending all the components we needed apart from the CPU and RAM, the only items they don't manufacture.

The resulting all-MSI build is at the cutting edge of current tech specs, thanks to its DDR5 and PCIe 4.0-compatible motherboard, and what's more, it's also pretty good value for money. Remember, adding the latest SSD and RAM to your build will increase its overall price, so if you already have some DDR4 RAM you want to use, go for the cheaper DDR4 model motherboard while you wait for DDR5 sticks to come down in price.

It's also worth noting that MSI provided its own keyboard, mouse, and monitor to complete the look, but we sadly didn't have space to include them. Rest assured, we'll cover them in a future issue. For now though, let's get on with the build!



THE INGREDIENTS

MSI SENT SOME fantastic components for us to work with—we're not talking money-no-object stuff (see Sam's water-cooled build on page 16 for that), but the type of components I'd choose if I was trying to spec out a value for money future-proofed system. Key to this is the motherboard, the MSI MPG Z690 EDGE WIFI ($310), which supports Intel's 12th generation processors, PCIe 4.0 SSDs, and DDR5 RAM. You can save $20-30 by opting for MSI's DDR4 version of the same board, which I'd recommend if you have existing RAM you can reuse, because DDR5 RAM is still just so ridiculously expensive right now.

Thankfully, PCIe 4.0 SSD drives aren't as much of a premium over their 3.0 equivalents, despite offering nearly double the speed. The MSI Spatium M480 PLAY 2TB ($330) is $100 more than a PCIe 3.0 equivalent like the Samsung 970 Evo Plus. MSI's drive seems custom-built to appeal to the PS5 market thanks to its giant heatsink, but this cooling will at least keep the storage cool during serious PC use. MSI provided a relatively low-end graphics card for this build, so if you have the budget, we'd recommend the 3060 or 3070 instead.

MSI's AIO cooler, the MEG CoreLiquid S280 is a dual-fan (2x 140mm) design. The MPG A1000G 1000W power supply is overkill, but gives plenty of overhead for future upgrades. A realistic power draw here is 480W, so we'd go for a 600W PSU.

For the CPU, Intel graciously offered an i9-12900K, which is total overkill when matched to the RTX 3050. For RAM, we found 32GB of Corsair's Vengeance DDR5-4800, again overkill for this system, but will definitely max out the performance of the chip.

INGREDIENTS

PART		STREET PRICE
Case	MSI MPG Sekira 100R	$120
Motherboard	MSI MPG Z690 EDGE WIFI DDR5	$320
CPU	Intel Core i9-12900K	$610
GPU	MSI GeForce RTX 3050 GAMING X 8G	$360
Memory	Corsair Vengeance 32GB (2 x 16GB) 4800MHz DDR5 C40	$285
PSU	MPG A1000G 1000W	$180
Storage	MSI Spatium M480 Play M.2 2280 PCIe 4.0 2TB	$330
CPU Cooler	MSI MEG CoreLiquid S280	$220
OS	Windows 11 Home 64-bit OEM	$32
Total		$2,438

1

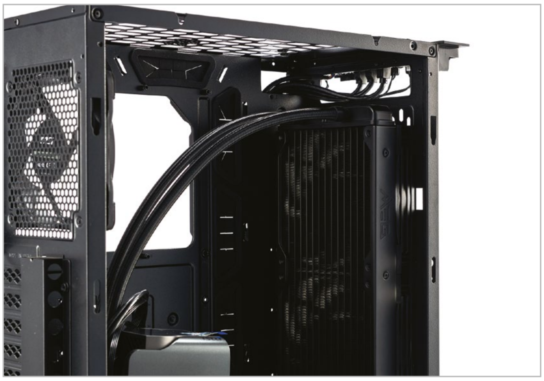
ENTER THE DRAGON

WE START WITH MSI's dragon-emblazoned Sekira 100R Case (see review on page 89)—a full-size chassis that's compact and won't take up a lot of space. The case comes with four RGB fans pre-installed—three of which are in the front and one at the rear. There's also space for two more fans at the top, which we'll end up using later (see step 7). The case is easy to take apart—a top panel keeps both the glass panel on the left side and the metal panel on the right stay in place. The trickiest part is the cable management on the rear, as you need to keep cables flat to slide the panel back on. We bent a set of pins on the RGB controller as a result of our messiness.

2

FANNING THE FLAMES

THE NEXT STEP was to install the radiator before doing anything else with the case. The front of the case features a window, but only halfway down the cover, meaning you can only see half of the RGB fans. I decided to remove all of the RGB fans from the front and put two of them at the top later in the build. I then installed the non-RGB fans that come with the cooler in the top part of the case front, as they'd be obscured by the metal part of the cover anyway. In hindsight, I should have made things easier and put the rad at the top of the case, but I still think it's better at the front. MSI's radiator is dead easy to install as it's relatively small, although the large cooling block is a little cumbersome. I removed the large plastic cover over the display to make the build a little easier.



3

CENTRAL INTELLIGENCE

NEXT, IT WAS TIME to start adding components to the motherboard while it was outside of the case. I started with Intel's chipset by unhooking the socket's arm, opening the latch, and simply dropping the chipset into place. It should sit comfortably on the motherboard with the writing on the chip facing up and not moving laterally once in place. The bracket requires a little force to hook it back under and hold the processor in place, but nothing to be afraid of. One challenge we faced was that MSI's cooler comes with an LGA1700 bracket for Intel chips but this wasn't included in our package—presumed missing after doing the rounds with other reviewers. No matter, we pilfered the bracket from Sam's NZXT H1 chassis and that worked fine. Make sure your cooler comes with the right brackets and order separately if needed.

4

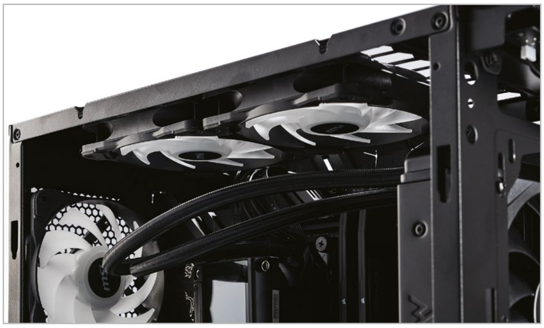
SPATIUM STATION

MSI'S SPATIUM M480 PLAY SSD isn't half chunky, coming as it does with a heatsink that makes it compatible with Sony's PS5 console. I removed the cover on the motherboard and had intended to reinstall the heatsink pre-installed on its cover. However, after opening the SSD drive's box, the first thing I saw was a warning against taking the heatsink off. I ignored this and began removing the screws on the drive holding it in place. It remained difficult to remove thanks to whatever adhesive MSI has used. "You win, MSI", I thought, and put the screws back in place and screwed the drive into the motherboard as is. One of the benefits of using all-MSI components is that everything matches, and looks pretty good to boot. Our photographer, Olly, who has an aversion to MSI's dragon logo, begs to differ, however.

7

RAISE THE ROOF

BEFORE ADDING the graphics card to the newly-installed motherboard, I figured I'd use two of the three RGB fans left over and add them to the ceiling as exhausts. Should I have done this before installing the motherboard? Sure! But this is only my second *Maximum PC* build, so it's a lesson for next time. Besides, these fans are relatively small and the mounting screws are screwed in from the top of the case on the outside, so it wasn't fiddly. The lighting on these fans is controlled by a pre-installed unit on the rear of the case, which has a single RGB connector that goes to the JRAINBOW1 header on the motherboard. This unit controls lighting only, so you need to connect the fan leads directly to the motherboard. Thankfully, this mobo has plenty of SYS_FAN headers for the five fans inside this case, so no problem there.



8

GRAPHIC CONTENT

MSI'S RTX 3050 GAMING X is fairly compact inside the case thanks to its twin-fan design. Before we install it, we need to remove two of the shields in the rear of the case. MSI's case design means that the screws holding these shields in place are covered by another metal shield, which has holes to get a screwdriver through. I found this fiddly and unscrewed the shield during installation. The RGB logo can be controlled by MSI's Mystic Light app. The graphics card also boasts a higher boost clock of 1845MHz over the standard 3050's 1777MHz boost clock for some minor performance gains. We also found the card relatively easy to buy, at the time of writing, indicating that it's of limited use to crypto miners or not profitable enough for scalpers. The only catch is that it's still $100 more than the RRP of the standard RTX 3050.

msi
GEFORCE RTX
EDGE

5

RAMPED UP

COMPLETING the motherboard construction phase of the build is the RAM. As this is a DDR5-compatible motherboard, we brought out the big guns—two sticks of Corsair Vengeance 16GB 4800MHz performance DRAM, which Corsair had kindly provided previously. We tried other manufacturers to see what DDR5 they had, but found it difficult to get anything—perhaps a sign of the low demand for the faster standard given the inflated prices or continuing low stock levels. At $285, this kit is nearly double that of Corsair's DDR4 Vengeance kits such as the LPX or RGB Pro. This is an area where you can save money without a huge performance hit, especially if you have DDR4 sticks already. If that's the case, opt for the DDR4 model of this motherboard, which will save you some money while you wait for DDR5 prices to fall.

6

COMBINING THE TWO

WITH THE MOTHERBOARD now sporting all components except the graphics card, it's time to get it into the chassis. However, we couldn't find the nine short screws required, probably because some of these components had been used elsewhere. Thankfully, we have a magnetized drawer of spare screws for such emergencies and with the motherboard in, it was time to connect the CPU cooler. We applied an LGA1700 mount on the rear of the motherboard, where there is a hole in the case. We then screwed the bracket around the four corners of the CPU, grabbed the cooling block, and used a screwdriver to tighten it into place. We made sure the tubes that connect the radiator to the block sat above the block itself, as it has an IPS display that shows the temperature, weather, and a host of other information.

9

WATT THE HECK

I'VE PUT IT OFF for as long as possible, but it's now time to install the power supply and connect the power cables. To MSI's credit, this stage is pretty easy thanks to its compact size and the fact that it's fully modular. I tend to work from top to bottom when it comes to power, so I start with the CPU power cable at the top of the motherboard, then add in the motherboard power cable, the GPU power cable, and the SATA power cable used for the fan lighting. The Sekira 100R comes with 3.5-inch hard drive bays at the bottom of the case, next to the power supply. Because I'm not installing any mechanical drives in this build, I unscrew this bracket to make as much room as possible for the power cables. While I'm at it, I remove the 2.5-inch drive bracket that sits just below the motherboard to make things look cleaner through the window.

10

CONNECTING WITH NATURE

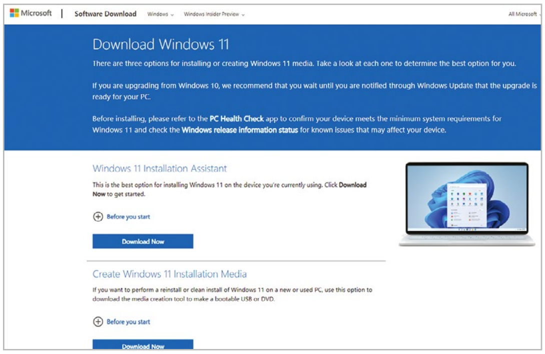
THE NEXT FIDDLY TASK is flipping the case on its side and connecting all of these power cables and header cables onto the motherboard. This isn't a massively roomy case, but it's still relatively easy to connect the cables where they need to go, and the all-black finish to the MSI components and cabling certainly appeals to the stealth fan in me. There is some RGB from the fans and the GPU when we turn it on, but I do like the uniform look of this all-MSI build. The most fiddly part of any build is connecting cables to the motherboard headers, and that's no different here—there are five fan power cables to connect all over the motherboard and we needed someone to hold a phone flashlight when connecting the various case headers such as reset and power button. We also added the plastic cover to the CPU cooler, which easily clips on with no screws.

11 TIE ME UP! TIE ME DOWN!

EXCITED TO GET ALL of the case panels back on and the system powered up, I was halted in my tracks by my less-than-stellar cable management. To my credit, I had been feeding excess cabling through the case's velcro ties but, as a result, created thick bunches of cables that put pressure on the side panel, preventing it from locking into place. In the process, I also pulled on one of the RGB cables and damaged two pins of the controller, which I bent back into place. I then spent 15 minutes releasing some of the cabling out of the ties, running it up to the holes in the top of the case, then tucking excess power cables behind the PSU, where there was plenty of space. The result isn't the cleanest looking back-panel I've managed, but MSI's various cables were nice and long and it won't be visible.

12 WIN-D'OHS

AFTER PUTTING THE CASE BACK TOGETHER, I headed to the Microsoft site on my laptop to create a Windows 11 installation disk and waited for it to download. After an installation error, a different USB stick fixed the issue. Windows 11 was installed within an hour, and one hour later, I'd performed the latest Windows updates, installed Nvidia's graphics software, and downloaded MSI Center from the Microsoft Store. Having one app to control all the computer's functions, from lighting to temperatures and overclocking, makes a nice change from using a myriad of different software. It also makes it easy to keep the motherboard drivers and firmware up-to-date to maximize the system's performance. MSI apps won't win any design awards, but it's all there if you want to tinker.



Download Windows 11

There are three options for installing or creating Windows 11 media. Take a look at each one to determine the best option for you.

If you are upgrading from Windows 10, we recommend that you wait until you are notified through Windows Update that the upgrade is ready for your PC.

Before installing, please refer to the **PC Health Check** app to confirm your device meets the minimum system requirements for Windows 11 and check the **Windows release information status** for known issues that may affect your device.

Windows 11 Installation Assistant

This is the best option for installing Windows 11 on the device you're currently using. Click **Download Now** to get started.

Create Windows 11 Installation Media

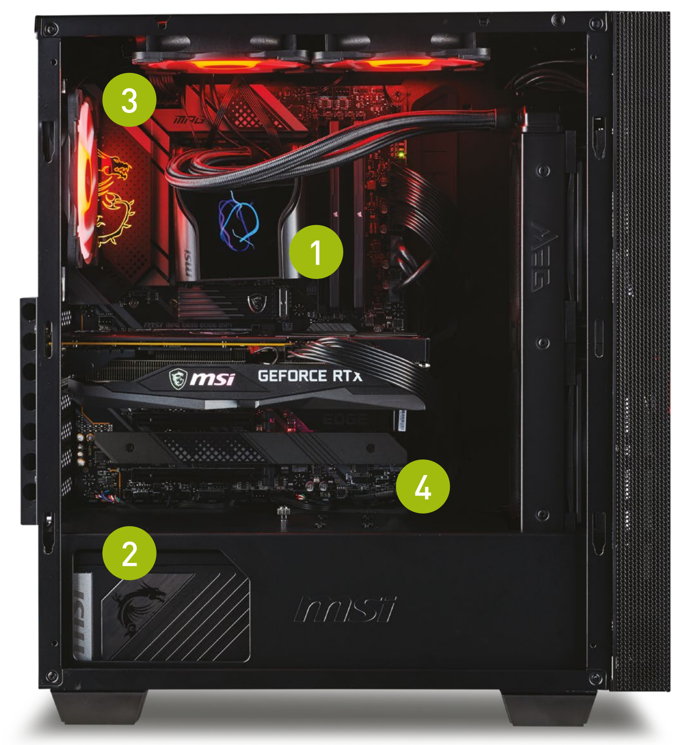
If you want to perform a reinstall or clean install of Windows 11 on a new or used PC, use this option to download the media creation tool to make a bootable USB or DVD.

© MICROSOFT

Join the conversation!

Discuss all things PC gaming with fellow readers at our official forums
forums.pcgamer.com

PC GAMER



1 MSI's CPU cooler comes with a 2.4-inch IPS display that can be configured to display information on the temperature, weather, images or video, and more.

2 We hope you're fans of the MSI dragon logo, as there are no less than four visible through the window of the case. We do like the uniformity though.

3 We like the restrained amount of RGB in the case, which just adds a splash of colour to an otherwise stealthy look.

4 This case comes with a removable 2.5-inch caddy below the motherboard, but we took it out to complete the clean aesthetic.

THE CONCLUSION

CREATING AN all-MSI build using its latest components was a fun and relatively trouble-free experience that resulted in a satisfyingly uniform look. The stealth black look on the major components helped the lighting on the fans, GPU, and heatsink block really pop, and I was particularly enamored with the relatively small footprint of the case itself.

Our benchmarks demonstrated a few interesting results as we opted to compare it to a couple of other recent Intel 12th generation builds. In both our April 2022 Intel 12th gen build and May 2022 Intel NUC build, we used the Gigabyte GeForce RTX 3050 Gaming OC card, which outperformed MSI's card by up to 20 percent in a couple of our tests, thanks to its higher core clock speed of 1822MHz compared to MSI's 1552MHz. At just $20 more, keep an eye out for Gigabyte's card if you're in the market for an RTX 3050.

On the positive side, MSI's Spatium drive lived up to its promised speeds, massively outperforming the PCIe 3.0 Samsung 980 drive in comparisons, and even outperforming the PCIe 4.0 WD_BLACK SN850 drive from last month's Intel NUC build, particularly on sequential write speeds. MSI's drive even keeps up with the best drives from our SSD group test in the previous issue, featuring the likes of XPG, Seagate, and Samsung.

The Cinebench score disparity was also eye-opening between the top-end i9-12900K in this build and the mid-range Intel Core i5-12400. The faster DDR5 RAM in this system may also have something to do with this, but given other benchmark tests, we suspect it's negligible. If you're doing a lot of CPU-heavy operations, it may be worth going for the more expensive i9 chip, or at least something in between. If you're a gamer though, it's clear that Intel's 12th gen Core i5 chip is more than enough when paired with the RTX 3050.

What are the benefits of going all-MSI on this build? Aside from a Windows 11 installation issue that required us to change USB flash drives, it was a simple build, but we'd expect that even if we had used different manufacturer's components. What we enjoyed most, though, was being able to use MSI's Dragon Center software in Windows to control every element of the system.

MSI also supplied us with a GK50 Low-Profile TKL Keyboard (reviewed in our March issue), a Clutch GM41 wireless mouse, MPG Artymis 273CQRX-QD monitor, and GV60 microphone—all of which could be managed from one single piece of software. On my personal PC, I run a Gigabyte motherboard, Logitech peripherals, and a Razer headset, and have so many different apps that I never bother changing the settings. It made me think about going single-manufacturer in my next personal build. See you next time! ⏻

BENCHMARKS COMPARISON

	ZERO-POINT	
3DMark: Fire Strike (Index)	14,995	14,757 (-1.6%)
CineBench R15 Multi-Thread (Index)	1,778	3,890 (118.8%)
CrystalDisk Q32T1 Sequential Read (MB/s)	3,557	7,106 (99.8%)
CrystalDisk Q32T1 Sequential Write (MB/s)	2,779	6,814 (145.2%)
Total War: Warhammer II (fps)	72	65 (-19.7%)
Rise of the Tomb Raider (fps)	113	107.55 (-4.8%)
Tom Clancy's Ghost Recon: Wildlands (fps)	57	49.62 (-13%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero point is April 2022's Intel 12th Gen Cover Build, which featured an MSI MAG Z690 Tomahawk DDR4, Intel Core i5-12400, Gigabyte GeForce RTX 3050 Gaming OC 8GB, Corsair Vengeance 16GB DDR4-3200, and Samsung 980 1TB SSD. All game tests are performed at 1080p at the highest graphical profile.

LAB NOTES

SAM LEWIS, STAFF WRITER

A long time coming

I've become obsessed with a game and, no, it's not Elden Ring

THIS MONTH, a certain game has been taking up my life and all I can think about is when I next get to play it. Regular readers will know about my love and nostalgia for this type of game, but I haven't spoken about this particular title as frankly I didn't want to jinx it. As you might have seen from the image to the right, the game is *Lego Star Wars: The Skywalker Saga*. I've been waiting excitedly for it for a year and a half now and, in the meantime, I tried to park the idea of it to one side. This plan worked pretty well as, all of a sudden, the release date crept up out of nowhere.

I've only had a few days playing the game and I can instantly tell that it's going to consume quite a lot of my time over the next few months at least. I've played a lot of the other games in the Lego lineup and the open-world ones are some of my favorites. So now that they've made this one more open, I'm thrilled with the amount of game I'm going to get through!

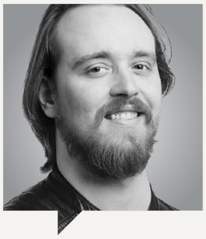
In fact, I started the game in order of the *Star Wars* films and have only played through the first main mission,. The rest of the time, I've been trawling every last corner of the open world in Mos Eisley.

Mos Eisley
Crash Site Memorial

***The Skywalker Saga* has become my all-consuming love.**

The level of detail is incredible and the same can be said for the graphics. Yes, I know it's 'only' a Lego game but hear me out… it's silky smooth and just kicking back on the couch after work and playing this on a 4K TV has been a great experience.

The game isn't a remaster either, each level is different from the ones in the *Complete Saga*, so it feels like a fresh new game, despite the *Star Wars* story being the same. It's the first game in ages that I'm going to struggle to put down and I've barely even scraped the surface yet. Yikes!



CHRISTIAN GUYTON

Staff Writer

I started a free trial of PC Game Pass this month, and I'm impressed. I've used subscription-based gaming services such as PS Now and Utomik in the past, but they struggle to feature the latest game releases, relying on a back catalog of older games. However, Microsoft has invested heavily in Game Pass, with plenty of big-name releases available on launch and a large library of titles, from triple-A to indie gems.

I also play games on PlayStation (I know, stone the blasphemer) and I'm curious about Sony's approach to the PS Plus service. Rolling PS Now into a tier-based Plus makes sense, but I'm apprehensive about paying more for the higher tiers.

PlayStation CEO Jim Ryan recently confirmed that Sony's biggest exclusives won't be available from day one on the new service, which feels like a cop-out in the face of Game Pass, but I'm intrigued by the prospect of playing old PS2 and PSP games. I have fond memories of Sony's handheld years (I'm one of the few who bought a PS Vita).

It will be interesting to see how the Plus platform performs against the Game Pass juggernaut because it is at least doing some things differently. I can't see myself paying for both—with limited time for gaming, one will be enough. It feels like a question of nostalgia versus new releases. Which do you think is more important?

© WARNER BROS INTERACTIVE ENTERTAINMENT

The RedMagic 7 Pro is the best attempt yet at making gaming phones a thing.

Editor's Pick:
Nubia RedMagic 7 Pro

Gaming smartphones: what are they good for?

UNLIKE MANY, I like gaming smartphones. In fact, I credit one for prying me out of the Apple ecosystem—I was sent a Black Shark 3 Pro phone for review, reluctantly gave it a go, and saw my *Call of Duty Mobile* K/D ratio improve so much it felt like cheating. I got so used to the 90Hz display, I couldn't go back to my iPhone.

I say "unlike many" because much like folding phones, I've never seen a gaming phone out in the wild. I was discussing smartphones with friends last year, and when we'd seen the usual Apple, Samsung, and OnePlus blowers, I took out my Lenovo Legion Phone Duel 2. I was immediately mocked for the phone's distinctly uncool RGB lighting, dual USB-C ports, and pop-out selfie camera—and many of these friends work in the games industry!

The RedMagic 7 Pro is the latest attempt to make gaming smartphones a thing, and while it may not expand the category's market share, it is the best attempt yet. First of all, it doesn't look like a gaming phone. The 256GB storage color, named 'Obsidian', doesn't even have RGB lighting (the 512GB 'Supernova' model does).

As expected, the phone is a beast when it comes to performance, with the latest Snapdragon 8 Gen 1 processor and 16GB RAM (our review model came with 18GB). That results in Geekbench scores unmatched in the Android world, although the iPhone 13 Pro does still beat it. For mobile gamers, buying the RedMagic 7 Pro is much like dropping a 3090Ti into your desktop—you can comfortably max out the settings on whatever you're playing. This means rock-solid 60fps performance in RPGs such as *Genshin Impact*, and even 120fps in MOBA game *Vainglory*.

The screen is a mixed bag, boasting a 120Hz refresh rate (good), 2400x1080 resolution (OK), and a 700 nits peak brightness (poor). It should be noted that the display is down from the 165Hz one on the standard RedMagic 7, for reasons we'll explain later. We did like the 960Hz touch sampling rate, making general navigation feel snappy and gaming very responsive.

Gaming phones aren't known for their cameras, and this RegMagic doesn't change that. There are three sensors on the rear—a 64MP main, 8MP ultrawide, and 2MP macro. They're fine in sunlight but struggle in low lighting. The big change on this phone, and presumably why RedMagic calls this a "Pro", is its under-screen front camera. This 16MP lens is fine for video calls but not for selfies, as the detail is a little washed out. There's no punch hole intruding on your game of *Fortnite*, but I prefer Lenovo's pop-out camera solution.

If you play a lot of games, you'll love being able to play using the triggers on this phone. They aren't tactile switches, although the phone can vibrate to imitate this feeling, but they offer a 500Hz touch sampling rate, making them responsive for driving games and shooters.

The phone does a good job of staying cool while gaming, especially if you engage the 20,000rpm fan from RedMagic's software (pop headphones on if you do). The phone sports a 5,000 mAh battery, the same capacity as Samsung's S22 Ultra flagship. It struggles to last over 10 hours, though the included 65W charger can fully recharge it in under 30 minutes.

As I mentioned last issue, I'll be keeping my Samsung Galaxy S22 Ultra, but I'll miss gaming on the RedMagic 7 Pro. If you care more about gaming than taking selfies, though, this is the phone for you. **–GC**

$799 (256GB version), www.redmagic.gg

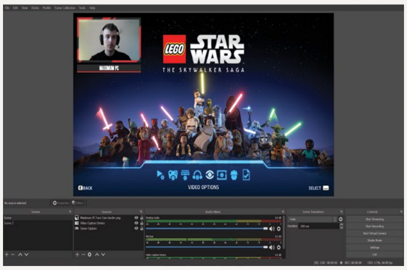
© REDMAGIC, OBS STUDIO

Reviewed...

74 Asus RTX 3090 Ti TUF Gaming

76 Velocity Micro Raptor Z55
78 Alienware 34 AW3423DW

80 Acer Nitro 5
82 Lenovo Legion 5i Pro (2022)
84 Acer ConceptD 7 Ezel Pro
87 NZXT Capsule
88 Razer Huntsman Mini Analog
89 MSI MPG Sakira 100R
90 Ghostwire Tokyo



92 OBS Studio vs. XSplit Broadcaster

Asus RTX 3090 Ti TUF Gaming

Fully armed and operational

MORE THAN A YEAR and a half has now passed since Nvidia launched its Ampere GPUs, including the RTX 3090 and RTX 3080. Ampere was supposed to bring the GPU empire under control but it was plagued by shortages in the ensuing time, an unforeseen weakness in Nvidia's plans. However, things are finally starting to improve and you might be able to find an RTX 3080 for under a grand. This is apparently unacceptable because the RTX 3090 Ti doubles that price, kicks performance per watt considerations to the curb, and goes for a no-holds-barred implementation of the GA102 processor.

The 3090 Ti, like its 3090 predecessor, packs 24GB of GDDR6X memory, but Nvidia has improved things with this update. Specifically, it's using 16Gb modules and only needs 12 of them, so all the chips are on the same side of the PCB. That's good news because GDDR6X temperatures have been a concern since the RTX 3090 launched, with some models, including Nvidia's Founders Edition, hitting 110°C under strenuous workloads. The Asus 3090 Ti TUF Gaming maxed out at 100°C, even with the memory overclocked from the default 21Gbps to 22.5Gbps and running an Ethereum mining test—something we couldn't have done with the old 3090 cards.

Yields on the chips have apparently improved as well, that or Nvidia has been stockpiling the best binned GA102 GPUs because the 3090 Ti uses a fully enabled processor. You get all 84 Streaming Multiprocessors (SMs) backing up the full 384-bit memory configuration. Nvidia also goosed the reference boost clock from the 3090's meager 1695MHz up to a heady 1860MHz—and Asus pushes that further to 1950MHz with the OC mode engaged via its GPU Tweak utility. That's still a conservative estimate, and we routinely saw core clocks of 2050–2080 MHz while gaming.

PAYING THE PIPER

But like everyone else, Nvidia had to pay the piper. The effective end of Dennard scaling (a 'law' from the 1970s that observed that smaller transistors required less voltage and current, meaning smaller process nodes ended up boosting performance per watt) and the death of Moore's Law (the doubling of transistor density every couple of years), means that while chips made on smaller process nodes might be faster, they tend to get there by increasing power use. In the case of the 3090 Ti, Nvidia has bumped the reference TBP (Total Board Power) from the 3090's 350W to a new high of 450W, and Asus goes even further with a peak power draw of nearly 500W when OC mode is engaged.

Naturally, more cores, faster clocks, and more power combine to create the blueprint for incredible performance. On paper, the RTX 3090 Ti delivers 8 percent more memory bandwidth and 12 percent more compute than the 3090. In practice, at least at 4K ultra, we measured an average frame rate improvement of 10 percent. At 1440p ultra, as well as in professional and content creation workloads, however, performance was only about 7 percent faster overall.

So, we're looking at 5–10 percent more performance, 30 percent more power, and a theoretical price that's 33 percent higher than its predecessor. That's certainly not an unassailable position. Hell, a bunch of teddy bears with spears could probably take it out if the stars were to properly align. But in the real world, vanilla 3090 cards still sell for $1,900 or more, the improved performance on the 3090 Ti might actually justify the price.

Before you whip out your credits looking to upgrade your gaming battle station, however, it's worth keeping one eye on the future. Sure, the RTX 3090 Ti might be the fastest thing since the Millennium Falcon, but the Ada architecture is likely only months away. If history is any indication of what to expect (see our GPU feature, page 26), Ada could provide a 50 percent boost in performance or more within the same tier of GPU. Power requirements might be a bit higher as well, but that's the new price for progress.–**JARRED WALTON**

BENCHMARKS

	RTX 3090 Ti	RTX 3090	RX 6900 XT	RTX 3080 Ti
10 Game Average (fps)	**108 / 70**	100 / 63	96 / 57	97 / 60
Borderlands 3 (fps)	**138 / 80**	122 / 70	131 / 70	118 / 68
Control (DXR)	**79 / 40**	70 / 35	47 / 22	69 / 34
Cyberpunk 2077 (DXR)	**50 / 25**	45 / 22	25 / 11	44 / 21
Far Cry 6 (fps)	140 / **91**	132 / 84	**141** / 86	130 / 82
Flight Simulator (fps)	**85 / 70**	87 / 64	80 / 51	80 / 54
Forza Horizon 5 (fps)	115 / 88	109 / 82	**130 / 91**	107 / 80
Horizon Zero Dawn (fps)	**162 / 102**	153 / 93	160 / 85	150 / 89
Minecraft (DXR)	**69 / 35**	64 / 32	31 / 15	62 / 31
Red Dead Redemption 2 (fps)	**133 / 94**	119 / 84	113 / 77	116 / 81
Watch Dogs Legion (fps)	**109 / 71**	102 / 65	98 / 58	98 / 63

Best scores are in bold. All testing conducted with a Core i9-12900K, MSI Pro Z690-A WiFi DDR4, 2x16GB DDR4-3600 CL16, 2TB Crucial P5 Plus M.2 SSD, Cooler Master MWE 1250 Gold V2. Scores are average framerates at 2560x1440 / 3840x2160 ultra, with ray tracing enabled in Control, Cyberpunk, and Minecraft.

VERDICT
7

Asus RTX 3090 Ti TUF Gaming

+ DEATH STAR Fastest GPU around; potent cooling; decent overclock.

− EXHAUST PORT Inefficient; extreme price; late to the party.

$2,149, www.nvidia.com

SPECIFICATIONS

Architecture	GA102
Lithography	Samsung 8N
Boost Clock	1950MHz
GPU Cores	10752
Memory	24GB GDDR6X
TFLOPS FP32	41.9
Bandwidth	1008Gbps
TDP	480W
Connectors	2x HDMI 2.1, 3x DisplayPort 1.4

TUF GAMING
ASUS

Asus pairs a triple fan and 3.2-slot cooler with an 8-pin power adapter to ensure the maximum performance from Nvidia's king.

VELOCITY micro
EVGA | GEFORCE RTX 3080 Ti
FTW3

This is the best performance PC right now for most buyers.

Velocity Micro Raptor Z55

Scary performance from this overclocked beast

WITH INTEL'S Alder Lake CPUs now firmly entrenched in the PC hardware market, we've been keen to see how far custom PC manufacturers can push them. Enter Velocity Micro, which has taken the already fearsome Intel Core i9 12900K, overclocked the eight Performance cores to 5.1GHz, and taken the eight Efficient cores to 4GHz. That maxes out the performance of this already impressive chip while pairing it with other bleeding-edge components, including a PCIe 4.0 SSD, DDR5 RAM, and a 3080Ti GPU.

If you're reading those specs and struggling to imagine what the price could be, let us put you out of your misery—the Raptor Z55 costs $4,999. That's a healthy chunk of change, but it's in the same ballpark as the similarly-specced HP Omen 45L ($4,700) and Corsair One i300 ($4,999), neither of which are supplied with the CPU overclocked. We loved the i300 when we reviewed it in our April 2022 issue, especially its svelte form factor, but the Raptor Z55's overclocked CPU delivered a 5 percent better Cinebench score than the Corsair.

The Raptor Z55 is also a more future-proofed machine, given the space inside to upgrade and add components. In fact, you'd be hard-pressed to find a PC with a bigger footprint, so you'll need plenty of desk or floor space, and don't plan on moving it much unless you have arms like Chris Hemsworth. However, there's loads of space for airflow and a tool-free side panel for when you need to get inside.

While the system features plenty of well-known brands, including a Gigabyte motherboard, EVGA GPU, and Samsung SSD, the case and cooling are all Velocity Micro's own. The case does an excellent job of showing off the company's neat and tidy installation, with a stealthy black design illuminated by the colorful GPU, fans, and RAM. Sadly, the triple-fan radiator is side-mounted in the front of the case, which is good for cooling but not for showing off the fancy lighting.

VIRTUALLY SILENT FANS

Given that there are also two ceiling fans and one exhaust fan, airflow is excellent, and the machine is virtually silent in normal operation and quiet even under full load—that's quite some feat given the overclocks. The CPU did go hot when performing our benchmark tests at 111°C, but it tends to peak at 100°C in gaming and 60°C under normal load.

With components at the cutting edge across the board, it was no surprise to see excellent benchmark results from the Raptor Z55. Aside from adding in a much more expensive 3090 or 3090 Ti GPU for incremental frame rate gains, there's not much more you could do to improve the performance of this system. While it's no doubt added significantly to the cost of this machine, the inclusion of 32GB of DDR5-5200 RAM and a PCIe 4.0 drive will keep it current for years to come.

On the graphics side, the RTX 3080 Ti has also been overclocked to 1,800MHz over the standard model's 1,670MHz. In reality, our benchmarks didn't deliver a massive performance boost in games when compared to the standard RTX 3080 used in our February 2022 build with the same CPU, but it was a strong performer at 4K, capable of running *Horizon Zero Dawn* at 91fps and *Hitman 3* at 127fps.

The closest comparison to this machine in terms of specs is the Corsair One i300. The Raptor Z55 is a more traditional gaming PC, compared with Corsair's sleeker, console-like build. Which one is best for you will depend on your taste—the Raptor Z55 is roomier and much easier to upgrade, whereas the One i300 takes up significantly less desk space and will fit neatly under the TV for weekend gaming sessions.

If you have $5,000 to play with though, there are two excellent systems available for different users who just want the best in PC tech in 2022. **–GUY COCKER**

VERDICT

8

Velocity Micro Raptor Z55

+ DINO-SOAR Incredible performance, supreme cooling, easy to build in.

– DINO-BORE Huge footprint, front lighting hidden behind case.

$4,999, www.velocitymicro.com

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	4,189	4,085 (-2.48%)
CrystalDisk Q32T1 Sequential Read (MB/s)	3,344	6,606.85 (97.57%)
CrystalDisk Q32T1 Sequential Write (MB/s)	2,911	4,935.41 (69.54%)
3DMark: Fire Strike Ultra (Index)	37,817	39,032 (3.21%)
Rise of the Tomb Raider (fps)	78	142 (82.05%)
Total War: Warhammer II (fps)	98	103.8 (5.92%)
Tom Clancy's Ghost Recon: Wildlands (fps)	69	72.2 (4.64%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i9 12900K, Corsair 32GB DDR5-5200 RAM, an Asus ROG Strix RTX 3080 10GB, Asus Rog Strix Z690-E Gaming WiFi motherboard, and WD Black SN750 2TB SSD. All game tests were performed at 3840 x 1600 at the highest graphical profile.

SPECIFICATIONS

CPU	Intel Core i9 12900K @ 5.1GHz
GPU	EVGA GeForce RTX 3080 Ti FTW3
RAM	32GB (2x 16GB) DDR5-5200
Motherboard	Gigabyte Z690 Aorus Master
Storage	2TB Samsung 980 Pro NVMe SSD
Front I/O	1x 3.5mm audio, 2x USB 3.2 Gen 1, 1x USB 3.2 Gen 2 Type-C
Rear I/O	4x USB 3.2 Gen 1, 5x USB 3.2 Gen 2, 2x USB 3.2 Gen 2 Type-C, 10GbE LAN, HD Audio, 3x DisplayPort, 1x HDMI
PSU	EVGA 850W SuperNOVA
OS	Windows 11 Home
Dimensions	20.25 x 20.5 x 8.25 inches
Weight	30lbs

At 0.1ms response, Alienware's new OLED monitor is much faster than any LCD monitor.

Alienware 34 AW3423DW

The best things come to those who wait…

THIS IS THE DAWN of a new age of screen tech. We give you the Alienware 34 AW3423DW, the first true OLED monitor for the PC. That's a qualified 'true' because it's not, strictly speaking, the first OLED monitor of any kind. Instead, it's the first aimed at consumers and marketed at a vaguely attainable price.

The AW3423DW is designed for gaming, where OLED promises much thanks to response times an order of magnitude faster than any LCD. But the basic form is entirely familiar. The 34-inch panel has a gentle 1800R curve, 21:9 ultrawide aspect ratio, 175Hz refresh, and 3,440x1,440 native resolution. It's right at the sweet spot, striking a balance between detail and frame rates.

Nothing radical so far, but make no mistake, this screen is special. Enhanced by quantum dot technology for ultra-vibrant colors, it's ridiculously quick. The rated response time is 0.1ms, five times faster than the quoted GTG response of the fastest existing IPS monitors.

Per-pixel lighting, perfect black levels and effectively infinite contrast are on the menu, too. Even the latest mini-LED LCD monitors with fancy local dimming can't compete. Alienware says the AW3423DW is good for 1,000 nits peak brightness, a decent figure by any measure and particularly strong for an OLED panel. Core specs aside, you also get Nvidia G-Sync Ultimate, wide color coverage including 99.3 percent of the DCI-P3 digital cinema space, and a three-year warranty covering OLED burn-in. There are also two HDMI ports and a DisplayPort socket, the former pairing limited to 100Hz refresh.

First impressions are underwhelming. In standard SDR mode, it doesn't feel like 1,000 nits. Inevitably, the pixel density of 110dpi is unimpressive on the Windows desktop and the OLED panel's triangular rather than rectangular subpixel structure interferes with Windows' ClearType font smoothing. If crispy fonts are your thing, stick with an LCD.

But this display needs to be in HDR mode to do its thing, including regular SDR content, for which you hop into the Windows Display Settings menu and ramp the SDR brightness up. The result is the kind of zingy all-round image you were hoping for.

Still, it's with HDR content in games where this monitor shines. The colors and contrast are explosive. Compared with most so-called HDR monitors, where games such as *Cyberpunk 2077* often look better in SDR mode, this Alienware sets new standards. Shafts of sunlight pop against dark backgrounds, while inky blacks contrast with neon lights.

The same goes for pixel response. Rip your mouse around its mat as fast as you like, the visuals remain clear and crisp. No LCD monitor comes close. One cautionary note involves the AW3423DW's ABL (Automatic Brightness Limiter) system. It's one of several anti-burn-in measures and it varies the overall panel brightness in response to what's on-screen. As these things go, it's not particularly intrusive.

That aside, this is a stellar monitor for gaming, likely the best we've seen. It's not even ridiculously expensive given the huge step forward it delivers. As an all-rounder, factors such as the pixel density and subpixel structure are limitations. But if the remit is gaming, this is as good as it currently gets. –**JEREMY LAIRD**

VERDICT
9
KICK ASS!

Alienware 34 AW3423DW

+ **CHRIS ROCK** Incredibly fast; true HDR performance; fantastic contrast.

− **WILL SMITH** Relatively low-resolution for the money; not a great productivity tool.

$1,299, www.dell.com

SPECIFICATIONS

Screen size	34-inch
Panel type	QD OLED
Resolution	3,440 x 1,440
Brightness	1,000 nits peak HDR
Response time	0.1ms
Refresh rate	175Hz
Viewing angle	178° H&V
Contrast ratio	1M:1
Color coverage	99.3% DCI-P3
Connectivity	DisplayPort 1.4, HDMI 2.0 x2, USB hub
Other	Nvidia G-Sync Ultimate, AlienFX lighting
Warranty	Three years, inc burn-in

Acer Nitro 5

Portable performance on a budget

AFFORDABLE GAMING laptops (and we use the word 'affordable' loosely here) are a tricky proposition. Of course, you could spend upwards of $3,000 on a high-end laptop with a powerhouse GPU and a 4K screen, but plenty of gamers want a desktop alternative that won't break the bank. Unfortunately, many of these laptops have, over the years, struggled to perform well enough to justify their price tags, with GPUs like the GTX 1650 and now the RTX 3050 just not quite measuring up.

Thank goodness, then, for the GeForce RTX 3060. It's the perfect budget GPU, balancing top-notch 1080p performance with relatively low power consumption and a sensible price—assuming you can get one at RRP. This is the graphics card at the heart of Acer's latest Nitro 5 laptop, a capable and flexible gaming machine priced at a wallet-friendly $1,129. There are cheaper (and more expensive) Nitro 5 models available, but our review unit sits in the middle of the bunch.

Joining the RTX 3060 is a Ryzen processor, the 5800H, a departure from the Intel chips more commonly found in Acer's gaming laptops. It's backed up by 16GB of DDR4 RAM and a 512GB SSD. It's all par for the course; there aren't any components or features here that we would be surprised to see in a budget gaming laptop, from the pedestrian selection of ports to the 1080p screen.

Fortunately, it works together rather well. Gaming performance at 1080p is solid in just about every game, only dipping below 60 frames per second at maximum graphical settings in the most demanding titles. Ray-tracing is an option for those who want it, with DLSS serving to provide more stable performance while RTX features are enabled. The CPU is also strong, with excellent performance in multicore workloads and plenty of oomph for CPU-bound games. Thermals were impressive too, with the laptop not feeling hot to the touch, even after stress testing, and the dual fans rarely making much noise.

The only area of our benchmarking process where the Nitro 5 fell down was the SSD speed test. Sequential read speeds sat at a respectable 2.5GB/s, but write speeds languished barely above 650MB/s, far lower than we'd expect from an M.2 drive. It's not likely to cause any massive issues but we were surprised at how slow it was considering that SSD speeds on gaming laptops are typically measured in the gigabytes.

There are other problems elsewhere, but nothing that compelled us to judge this Nitro 5 too harshly; it still has the same bog-standard 1080p LCD panel found on other Nitro 5 models, which is a little dim and doesn't have particularly great color reproduction, but still brings a 144Hz refresh rate, which is arguably more important for gaming. The screen bezel is a bit chunky for our liking, too, and the black plastic of the chassis is a fingerprint magnet.

The keyboard feels good to use for both typing and gaming, with only a little noticeable flex on firm keypresses. Our review model comes with four-zone RGB backlighting, which is an optional extra (the standard model has red LED backlights). The trackpad is decent too, with a satisfying click and smooth surface. The speakers are nothing special and we'd recommend using a headset, but they're good enough for this price point.

Our big bone of contention with this Nitro 5 is the battery life. Gaming laptops aren't known for their battery longevity, but the Nitro 5's 53Whr battery simply doesn't hold up to extended use. If you're doing intensive work on the go, don't expect to get much more than a couple of hours out of this machine, unless you're running it on maximum eco settings.

This laptop won't set the world on fire but it does offer a fantastic price-to-performance ratio that isn't matched by the majority of budget gaming laptops on the market. For a first laptop, a cash-strapped student, or a gaming machine to get your kid off the family PC, the Nitro 5 is a solid choice. **–CHRISTIAN GUYTON**

VERDICT
7

Acer Nitro 5 AN515

+ NITROUS OXIDE Very reasonable price tag; RTX 3060 performs well; runs quiet and cool.

− CARBON MONOXIDE Screen is bland; underwhelming drive speed; battery life should be better.

$1,129, acer.com

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	1,030	2,017 (96%)
CrystalDisk QD32 Sequential Read (MB/s)	3,374	2,369 (-30%)
CrystalDisk QD32 Sequential Write (MB/s)	2,530	652 (-74%)
3DMark: Fire Strike (Index)	13,610	17,524 (29%)
Rise of the Tomb Raider (fps)	92	117 (27%)
Total War: Warhammer II (fps)	62	93 (50%)
Tom Clancy's Ghost Recon: Wildlands (fps)	49	65 (33%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our gaming laptop zero-point is the Acer Predator Triton 500, with an Intel Core i7-8750H, Nvidia GeForce RTX 2060 Max-Q, and 16GB of DDR4-2666. All game tests are performed at 1080p at the highest graphical profile.

SPECIFICATIONS

CPU	AMD Ryzen 7 5800H
Graphics	Nvidia GeForce RTX 3060
RAM	16GB DDR4 @ 3200MHz
Screen	17.3-inch 1080p LCD IPS screen @ 144Hz
Storage	512GB M.2 NVMe SSD
Ports	1x 3.5mm Combo Audio Jack, 1x HDMI, 2x USB 3.2 Gen 1 Type-A, 1x USB 3.2 Gen 2 Type-A, 1x USB 3.2 Gen 2 Type-C, 1x RJ45
Connectivity	Wi-Fi 6, Bluetooth 5.2
Weight	5.95lbs
Size	15.9 x 11.0 x 0.98 inches

Lenovo Legion 5i Pro (2022)

Great performance at a great price

LAST YEAR'S LENOVO Legion 5 Pro laptop won many fans by packing an AMD Ryzen 5 5600H processor, RTX 3070 GPU, and 16-inch 16:10 display into a 15-inch chassis and a $1,600 price tag. It was released at a time when being able to buy a desktop 3070 was near-impossible, and it marked itself out as one of the best value gaming laptops on the market as a result.

The 2022 version of the machine is here, albeit in Intel form (the "5i" moniker signifying the Intel version—an AMD model will follow later this year). The Legion 5i Pro is a significant step forward from a tech perspective, with Intel's 12th gen i7-12700H also allowing for the inclusion of DDR5 RAM as well as a PCIe 4.0 SSD. Other improvements include a Wi-Fi 6E card and an RTX 3070 Ti 8GB, with a better cooling system than last year's model. The 16-inch, 2560x1600 G-SYNC enabled IPS display seems to be the same as before, which is no bad thing.

The 5 Pro sits between the Legion 5 and Legion 7 models. The Pro has that gorgeous 16-inch screen but lacks the 7's RGB lighting around the edge (there is four-zone RGB on the keys). That screen is the star attraction, with the extra vertical space allowing you to game at higher 1440 or 1600 pixel resolutions, as well as helping content creators who need more space for timelines or office tasks such as word processing and spreadsheets.

Whatever you're doing on the Legion 5i Pro, though, it's an absolute pleasure to use. Games run brilliantly and look spectacular on the screen, and newer titles such as *Forza Horizon 5* run at over 60fps at max settings in native resolution. There are three power settings—Quiet, Balanced, and Performance. The machine is quiet, but not silent, at the lowest setting and it gets loud in performance mode, although not as loud as laptops we've tested from Dell and HP.

GETTING BETTER

There are a couple of smaller improvements to this year's model. The light-up helmet logo on the lid is gone, in favor of a much more subtle 'Legion' logo. There's an extra USB-C port for a total of three, one of which supports Thunderbolt (this is an Intel machine, after all). And the wired network port on the rear has the release latch facing up, making it much easier to unplug.

It's not all good, however. This is a chunky laptop, with the body weighing 5.63lbs and the massive 300W power brick adding another 2.33lbs to your backpack. For that reason, we wouldn't recommend it to anyone looking to take it out with them often, but if all you're doing is working, you can take a much smaller USB-C charger out—you need the big brick for gaming though. Lenovo supports up to 135W Power Delivery, not that we could find any such charger available, but our 100W charger worked just fine. Battery life overall isn't great, though, and you may want to disable the discreet GPU completely if you're not plugged into the wall. Sadly, that requires a restart each time, which can be annoying if you game a lot.

Upgradeability on the machine is good, thankfully, although we found the chassis to be tougher to open up than last year. We wish the machine boasted 32GB of RAM, although with the jump to DDR5 this would, of course, add to the cost. Thankfully, PCIe 4.0 SSDs don't come with quite as much of a premium, so we added a Samsung 980 Pro 2TB drive to the machine's second SSD slot, to offer a bit more storage for our game library.

If you're looking for a great gaming laptop that offers great bang for your buck, then the Legion 5i Pro needs to be on your shortlist. **–GUY COCKER**

VERDICT
9

Lenovo Legion 5i Pro

⊞ **ROMAN LEGION** Fantastic screen; ample power; great connectivity.

⊟ **ROMAN BATH** Heavy; huge power brick; only 16GB RAM.

$1,899, www.lenovo.com

GAMING LAPTOPS BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	1,415	2,741 (93.7%)
CrystalDisk Q32T1 Sequential Read (MB/s)	6,781	7,043 (3.9%)
CrystalDisk Q32T1 Sequential Write (MB/s)	4,968	3,696 (-25.6%)
3DMark: Fire Strike (Index)	22,591	24,258 (7.4%)
Rise of the Tomb Raider (fps)	158	144.12 (-8.8%)
Total War: Warhammer II (fps)	122	117.4 (-3.8%)
Tom Clancy's Ghost Recon: Wildlands (fps)	77	79.66 (-3.5%)

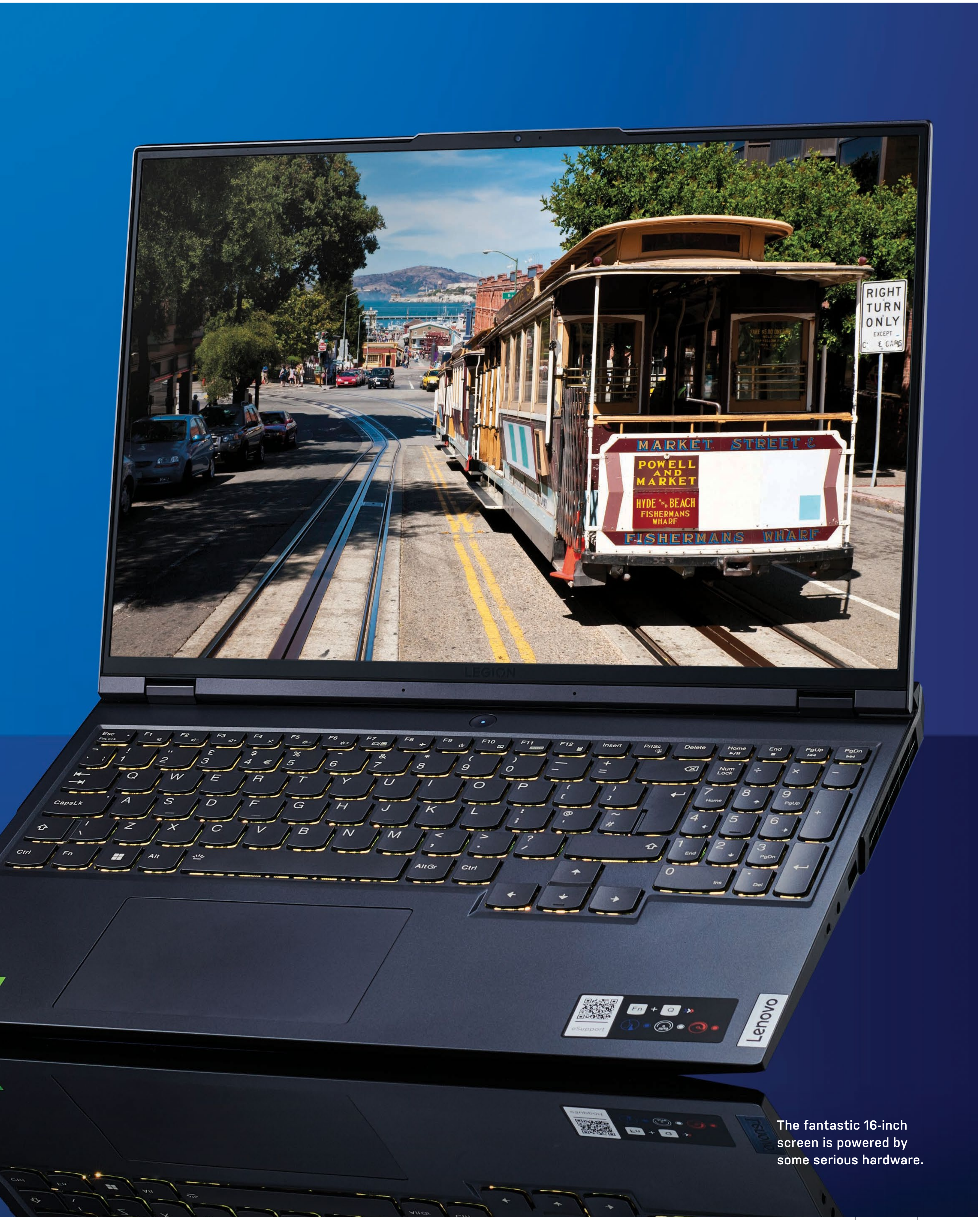
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point is the MSI GE76 Raider reviewed in our Holiday 2021 issue, consisting of an Intel Core i9-11980HK, 64GB DDR4-3200 RAM, Nvidia RTX 3080 16GB, and PCIe 4.0 2TB SSD. All game tests were performed at 1080p at the highest graphical profile.

SPECIFICATIONS

CPU	Intel Core i7-12700H
GPU	RTX 3070Ti
RAM	16GB (2x 8GB) DDR5-4800MHz
Storage	1TB PCIe 4.0 NVMe SSD
Side I/O	1x USB 3.2 Gen 1, 1x headphone, 2x USB-C 3.2 Gen 2 (1x Thunderbolt 4)
Rear I/O	2x USB 3.2 Gen 1 (1x always-on), 1x USB-C 3.2 Gen 2 (inc. power delivery), 1x HDMI 2.1, 1x RJ45, 1x DC-In
OS	Windows 11 Home
Dimensions	1.05 x 14.17 x 10.4-inches
Weight	5.63lbs

intel
CORE
i7
GEFORCE
RTX



The fantastic 16-inch screen is powered by some serious hardware.

Acer ConceptD 7 Ezel Pro

It ain't cheap, but it is intriguing…

IT'S ALL TOO EASY in this job to become blasé, to think you've seen it all before. So, in that sense, the Acer ConceptD 7 Ezel Pro is thoroughly refreshing. It's not truly unique, nor is it entirely issue-free. But it is unusual and it does some things so well that it makes conventional clamshell laptops seem clunky.

The showbiz bit involves the clever dual-hinged display. It's an ergonomic design that unlocks an entire universe of input options you didn't even know existed. Combined with the bundled Wacom EMR input pen, which slots neatly into the side of the screen, the result is a rather remarkable productivity tool for digital artists and other content creators.

The not-quite-unique bit involves the Microsoft Surface Laptop Studio, which offers a similar—but not quite identical—dual-hinged display. Acer's version of the dual-hinge offers an impressive six different modes or positions. First up, you can use it as a conventional clamshell laptop or fold the display flat and create an admittedly chunky tablet.

'Stand' mode has the screen forming a tent over the keyboard, 'Share' positions the screen facing up and parallel to the keyboard, while 'Display' is a clamshell presentation mode with the screen reversed. Finally, there's 'Float', which is arguably the most intriguing option. You use the device like a laptop, just with the bottom of the screen hinged forward, bringing it much closer and essentially 'floating' over the keyboard.

The clever bit is that Acer has engineered sufficient stiction into the mechanism to make it viable to use this position with the input pen. Critically, Microsoft's Surface Book Studio doesn't do anything like this float option.

Ambi-dextrous hinge aside, there's plenty more on offer. The 15.6-inch 4K touchscreen display is an absolute corker. For colors, contrast, viewing angles, and pixel density, it absolutely rocks. It's also Pantone-validated, which is useful for certain print-related workflows but doesn't actually imply anything particular about outright color fidelity.

The only obvious downside of the screen is the slightly grainy coating that comes with the touch input. It's not a major issue but does reduce clarity. It's also worth noting that it only runs at 60Hz, whereas the Microsoft Surface Book Studio does 120Hz, the higher refresh being advantageous in terms of input latency when using the pen.

A DECENT COMBO

Specs-wise, our review unit was running some slightly out-of-date chips in the form of an eight-core 10th gen Intel Core i7 processor, plus Nvidia's GeForce RTX 2070 graphics. But you can order it with 11th gen CPUs and Nvidia 30 series graphics, which would be a decent combo for the content creation remit. 16GB of RAM and a 1TB NVMe SSD fill out the final performance-relevant details. As for connectivity, on the left of the chassis, you get dual USB Type-C with full Thunderbolt 4 ports, a single USB-A, and the headphone jack. On the right, there's another USB-A, HDMI, a full-sized DisplayPort socket, and ethernet.

Overall, this is still a pretty quick machine. It's just at this price point the older hardware is a little tough to stomach. A battery life of around six hours of video playback isn't going to scare a MacBook, either. What's easy to appreciate, however, is the build quality.

This is a nicely engineered laptop throughout, with a solid keyboard bed, albeit all that deep-down integrity ends up weighing 2.5kg. Oh, and the keyboard backlighting is completely useless and we'd prefer a larger trackpad.

All of which means the Acer ConceptD 7 Ezel Pro is far from flawless, but it is pretty delightful nonetheless. As a portable tool for digital artwork, it's very special indeed. For more conventional image and video editing workflows, it's a little less convincing, thanks mainly to the CPU and GPU specs.

For the money, you can get clearly faster and more up-to-date machinery in that regard. But even in this configuration, it's hardly a slouch. And if its particular set of talents is something you might appreciate, there's nothing else like it. Even just as an alternative to the clamshell crowd for regular computing tasks, it's appealing. **–JEREMY LAIRD**

VERDICT

8

Acer ConceptD 7 Ezel Pro

⊞ **BUILT TO LAST** Clever dual-hinge engineering; fabulous 4K screen.

⊟ **LONG IN THE TOOTH** Aging CPU and GPU; quite heavy; limited battery life.

$3,000, www.acer.com

BENCHMARKS

Cinebench R23	8,936pts
X265 HEVC 4K video encode	5.89fps
Geekbench single core	1,319pts
Geekbench multi-core	7,647pts
Geekbench CUDA graphics	82,979pts
1080p video playback	6h12m
CrystalDiskMark read / write	3,542MB/s / 2,794MB/s
CrystalDiskMark 4K QD1 read / write	67MB/s / 111MB/s

SPECIFICATIONS

CPU	Intel Core i7-10875H
Graphics	Nvidia GeForce RTX 2070
RAM	16GB
Screen	15.6-inch, 4K, IPS, 400 nits
Touch input	Multi-touch, Wacom EMR stylus
Storage	1TB NVMe SSD
Ports	2x Thunderbolt 4 (USB-C), 2x USB-A, HDMI, DisplayPort, SD card slot, 3.5mm headphone jack
Connectivity	Wi-Fi 6, Bluetooth 5.2
Webcam	720p
Weight	2.5kg

Acer's unusual dual-hinge laptop makes for a great content creation tool.

SUBSCRIBE TODAY

Find your next great read

On iOS & Android!

Subscribe today and get instant access on your iPad, iPhone or Android device. Additional print options available.

www.magazinesdirect.com/B2XMPC

NZXT Capsule

A leap of faith or a comfortable transition for NZXT?

WHEN WE THINK of NZXT, the picture that springs to mind is a case company with a clean design language and reputable build quality. So when the company started to branch out into peripherals, we had plenty of faith that the brand could produce a range of items of the same caliber as its cases. A move over into the audio world wasn't the most obvious choice, but the company has gone all out with the NZXT Capsule microphone. So, was this a wise decision by NZXT, and does the Capsule match the level of quality of its cases?

The Capsule certainly fits nicely into the rest of NZXT's lineup. There are two versions, one in white and one in black, both of which get our seal of approval. With a crisp cylindrical design, it has a more professional look than most mics, and could be used in a range of locations. The compact footprint makes for a more discrete addition to your desktop and, with a tripod mount below, it can also be mounted elsewhere.

There is no garish RGB, only a small ring light on the bottom that glows white when the mic is active and red when you're on mute, a small and subtle detail that helps the efficiency of using the mic. We all know how frustrating it is when you don't realise you're muted and the ensuing cries of "you're on mute!".

It feels nice and hefty, weighing in at just under 2lbs, which gives a feeling of solid build quality. Made from extruded aluminum and PC ABS plastic, it feels premium for the most part. The majority of the weight comes from the stand which has a grippy rubberized base. Although it isn't the tallest stock stand, it has a great function. On the back of the Capsule is a quick-release button to detach the stand from the microphone without fiddling around with any screws. Also included in the box is a cap that fits on the back and covers the hole, which is nice attention to detail.

However, the quality is lacking a little on the biggest contact point of the microphone, its two volume knobs. On the front of the Capsule, there are two dials, one for the microphone volume and the other for headphone volume. The top microphone dial also doubles as a mute button but it feels a little loose and cheap. The bottom dial is still made of the same cheap-feeling plastic but as this is solely a dial, it doesn't wobble as much. These dials also don't have a stopping point, which we would prefer as they spin infinitely. That makes it hard to tell what levels you're at without seeing it digitally on your PC.

A MATCH FOR ITS RIVALS

Enough of the nitpicking, how does the NZXT Capsule perform? In terms of its specs, it is more than a match for its similarly priced rival mics on the market with a 24-bit/96kHz sample rate. This provides you with more than enough data to play with and tons of depth in the recordings. It doubles the bit/sample rate of most standard headset microphones, so if you're thinking of upgrading, a standalone microphone is a good route to take.

Stats aside, the Capsule records warm and detailed sound through its cardioid pickup style. Although this is a pretty standard pickup pattern, it is the only available recording mode for this microphone, so you'll have to make sure you are talking straight towards the Capsule to get the best audio recording.

For NZXT to make the move into the world of audio tech was a bold step and it has produced a well-rounded device. At around the $130 price point, there are a few offerings from brands such as Elgato, MSI, and HyperX and this Capsule mic can stand up strong against them. It doesn't quite have the features that MSI's first stand-alone microphone offers as the MSI option provides multiple pickup patterns. However, it has a similar high-quality plug-and-play sound with plenty of clarity whilst keeping background noises to a minimum.

Even in environments with fans and mechanical keyboards nearby, it managed to pick up our voice recordings well. If you're after a warm-sounding and sleek microphone that can be used for streaming, gaming, or in a more professional setting, this NZXT Capsule can tick those boxes comfortably. It continues with NZXT's long line of high-end products with only the dials on this device letting the quality side down a little. **–SAM LEWIS**

VERDICT
8

NZXT Capsule Mic

➕ **A NEW CHAPTER** Compact microphone; plug and play; rich detailed recording; quick release stand.

➖ **MISSING PAGES** Poor dial controls; lack of pickup patterns.

$130, www.nzxt.com

SPECIFICATIONS

Sample rate	96kHz
Bit rate	24-bit
Frequency response	20Hz-20kHz
Recording modes	Cardioid
Connection	USB Type C to Type A
Weight	1.94lbs

Razer Huntsman Mini Analog

Small but mighty keyboard

WHAT DO CONTROLLERS have over the reliable old keyboard-and-mouse combo? How can they hope to match the unerring precision of the mouse? How can they keep up with less than 20 buttons to press? Pfft. There's absolutely no reason to use a controller, no sir. No reason whatsoever. Except...

Yeah, alright, analog sticks are great. Variable input force has long been an advantage of rocking a gamepad in all sorts of games, from racing titles to shooters and fighting games. The ability to move your avatar or turn your vehicle slowly, delicately, with a single sustained input rather than constant anxious key-tapping, can be an oft-underrated boon. Fortunately, keyboards are catching up.

The Huntsman Mini Analog isn't Razer's first foray into using analog-input key switches, nor its first attempt at a 60 percent keyboard. The original Huntsman Mini was a fine example of a compact gaming keyboard, while the Huntsman V2 Analog offered Razer's flashy switches in a full-scale layout. What we have here is a mashup of those two keyboards, the best of both worlds.

It should go without saying that you need to be comfortable with the 60 percent layout to get the most out of this keyboard. There's no numpad, no dedicated function, or media keys, and everything is squeezed together for the smallest possible overall size. It's impressively lightweight but sturdy, ideal for tossing in a backpack for LAN parties or maintaining a minimalist gaming space. The detachable USB-C to USB-A cable is braided for improved durability.

The keycaps are doubleshot PBT with a nice textured feel to them and will never lose their labeling through heavy use. More than half the keys have secondary functions printed on their front-facing sides, to make executing additional commands more intuitive. Beneath those keycaps lurk Razer's proprietary Analog Optical switches, which promise more precise movement control, superior lifespan, and adjustable actuation levels.

So, how well do they work in practice? The variable analog input is fantastic; moving and steering in games feels amazing, with a gentle push providing slight movements while a firm press sees you fully commit to a direction. The adjustable actuation is great too; setting the actuation point high gives you ultra-twitchy responsiveness while dialing it down makes for a more comfortable typing experience.

One lauded feature of the Razer Analog Optical switches is the option for 'dual-step actuation', which allows you to map two different commands to one button. The first command triggers upon initial actuation, with the second activating when you further depress the key. Razer suggests this could have a plethora of uses for two-action combos in games, and it does to a certain extent. We tried using it for equipping and then throwing a frag grenade in *Apex Legends*, which worked reasonably well in a pinch, but actually trying to use those two commands separately is tricky. It strikes us as a niche feature that many players aren't likely to use.

Another point of contention here is the price. At $150, the Huntsman Mini Analog is expensive for a compact keyboard, especially considering that it doesn't come with any add-ons (a wrist rest would have been nice). The standard Huntsman Mini is $30 cheaper, for comparison, while HyperX's excellent Alloy Origins 60 costs $111. If the analog switch features are something you would use regularly, the extra price is justifiable.

No Razer product review would be complete without our usual commentary on the bundled customization software, Razer Synapse (and Razer Chroma, and Razer Cortex, and... you get the idea). It's still a rather arcane program to use if you aren't familiar with it, and it's a necessity to get the most out of this keyboard. Still, the Mini's per-key RGB is pretty, and the software provides an extensive level of control over your lighting, hotkeys, and switch actuation. Overall, this is a top-notch compact keyboard for the serious gamer. **–CHRISTIAN GUYTON**

VERDICT

8

Razer Huntsman Mini Analog

+ HUNTER Excellent build quality; precise optical analog switches; lots of customization options.

− HUNTED Expensive for a compact keyboard; no wrist rest; dual-step actuation is a bit fiddly in practice.

$150, razer.com

SPECIFICATIONS

Switch Type	Razer Analog Optical
Switch Durability	100 million presses
Media Keys	Integrated alt-keys
Connection	USB-C to USB-A
Battery Life	N/A
Wrist-rest	N/A
Dimensions	11.6 x 4.1 x 1.5 inches

MSI MPG Sekira 100R

A compact, subtle and well-specced case for the money

MSI MAY BE more commonly known for producing motherboards and graphics cards, but recently, it's been making an effort to break into the PC case market. The MSI MPG Sekira 100R is one of its newest cases to arrive, bringing to the market a mid-tower that includes a well-stocked front I/O panel, tempered glass, and four ARGB fans. What's not to like?

At first glance, you notice the vented top panel and a two-tone front that is split with a brushed aluminum-style finish to the top and glass to the lower half. It's a unique look, especially when you light up the case, something made easier by the included 1-6 ARGB controller that connects to your motherboard for seamless Mystic Light integration. Lighting can also be controlled via the front of the case, located as part of the front I/O compliment, where you can switch between profiles using what MSI calls the Insta-Light Loop Button.

Gaining access to the interior is a bit different though, as you have to remove the top panel first, which then allows you to remove both of the side panels. Pulling off the front panel reveals a full-length, clip-in dust filter, while the top receives a magnetic version. The front panel, though solid to the face, includes wide vents on each side to allow plenty of fresh air to reach the front three fans. With some cases, you might feel nervous when pulling off side panels but, on the Sekira 100R, everything both looks and feels well built.

Internally, there's a fairly standard layout, a large cutout area for installing CPU coolers, and a good number of tie-off points for cable management situated around the motherboard tray. One nice touch from MSI are the extra cable grommets, located near the front of the case, for passing fan cables through to the rear. These are nicely complemented by velcro tie-downs to keep all those cables tucked neatly into place. Not everyone is a fan of basement shroud cutouts to show off your power supply, but MSI has included this, with a 2.5-inch SSD mount to the top, and a second 2.5-inch drive mount located behind the motherboard tray.

FINDING EXTRA SPACE

Moving deeper into the case, the power supply basement can soon start to feel cramped. There's a dual 3.5-inch drive bay cage fitted here that can be removed, and should you wish to use anything but the most compact ATX power supply, you'll soon be needing that extra space. Our final dust filter is found in this area too, a slot-in sheet that helps protect the fresh cold air coming in from under the case. There's a reasonable amount of ground clearance to the bottom of the case too, helping to keep our power supply running well.

The MSI MPG Sekira 100R will set you back around $110, for which you are getting a lot for your money, especially with the included fans, decent front I/O, and ARGB hub. As extras, these items can easily add up and so, if you're on a tighter budget, it's important to have them included. The Sekira 100R doesn't do anything particularly special, but what it does, it does really well. While the case can support radiators, going with anything more than an All-In-One wouldn't make sense here. This is a case for a sensible build that is more about function with a hint of beauty and style. The black stealth look is nice and sleek, but a white version would have been a nice option to have too.

If you're looking for a new case that's well built and doesn't need any additional work to make it fully functional, then the Sekira 100R is hard to overlook. MSI has done a great job here with little to pick out in terms of faults. Sure, it's not perfect, but as it manages to stay on the budget side, even with everything that's included, this is a case we wouldn't hesitate to recommend. **–KRIS BUTTERILL**

VERDICT 7

MSI MPG Sekira 100R

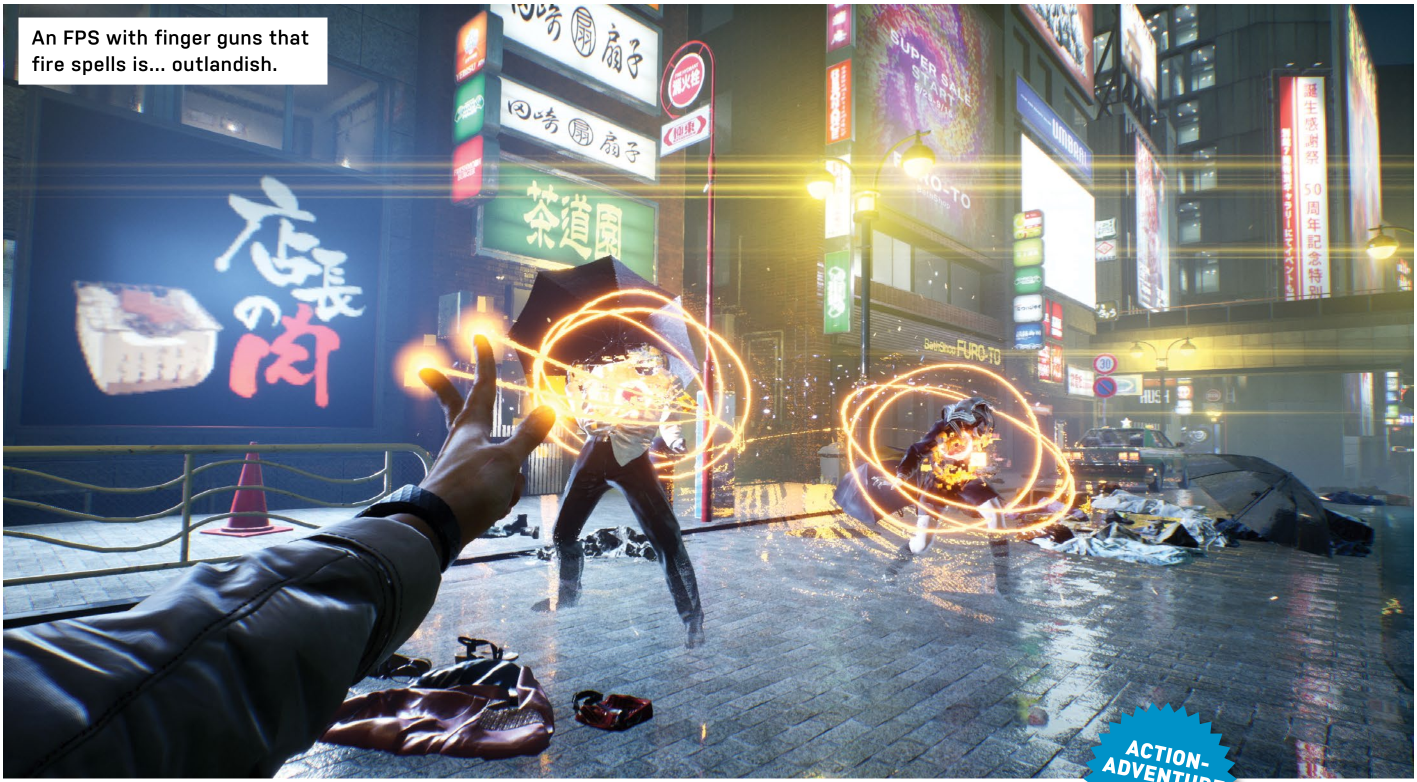
+ MYSTIC LIGHT Four ARGB fans included; lighting hub included; extras are a bonus at this price.

− MYSTIC FRIGHT PSU basement will soon fill up, especially if you need to use the 3.5-inch drive cage.

$110, www.msi.com

SPECIFICATIONS

Motherboard Support	ATX, Micro-ATX, Mini-ITX
2.5 / 3.5-inch Drive Support	2x 2.5-inch, 2x 3.5-inch
Max Radiator Support	Top, 240mm Front, 360mm Rear, 120mm
Fan Support	Top, 2x 120mm; Front, 3x 120mm, 2x 140mm; Rear, 1x 120mm
Dimensions L x W x H	16.5 x 8.4 x 18.7 inches
Graphics Card Clearance	13.4 inches
CPU Cooler Clearance	6.7 inches



An FPS with finger guns that fire spells is... outlandish.

ACTION-ADVENTURE GAME

Ghostwire Tokyo

The city that doesn't want you to sleep

A CURIOSITY IN FORM as well as function, *Ghostwire Tokyo* is in some ways a callback to Japanese horror games of the early 2000s (although this is much more of an action game), and also a graphical monster capable of serving up spectacular slices of neon lights and ray-traced reflections.

To call the story outlandish would be something of an understatement, but it's a good word to start the review off with. Everyone in Tokyo is dead, or at least gone, reduced to piles of clothing that lay where they fell when the body was somehow removed from them. Instead of its once bustling population, Tokyo is now home to a huge population of escaped pets looking for attention and rather a lot of ghosts and other visitors taken straight from Japanese folklore.

A first-person shooter with finger guns that fire spells instead of little bits of metal, *Ghostwire Tokyo*'s main character Akita has gained supernatural powers and the ability not to be one of those piles of clothing on the sidewalk, having been saved from a motorcycle crash by a spirit detective. His sister's been kidnapped too, providing more motivation than one man needs to go up against a ghost army.

He's not one man, though, thanks to the spirit riding shotgun in his body and supplying his new powers, but still, the pull to explore this remarkable vision would be strong enough on its own. Much of the time you crouch in cover, charging a spell before popping up, letting it rip, and enjoying the view of both the city backdrop and the inevitable explosion. Powers are based around the four elements, with wind as your basic machine gun. Damage enemies enough, and they expose their core which must be ripped out.

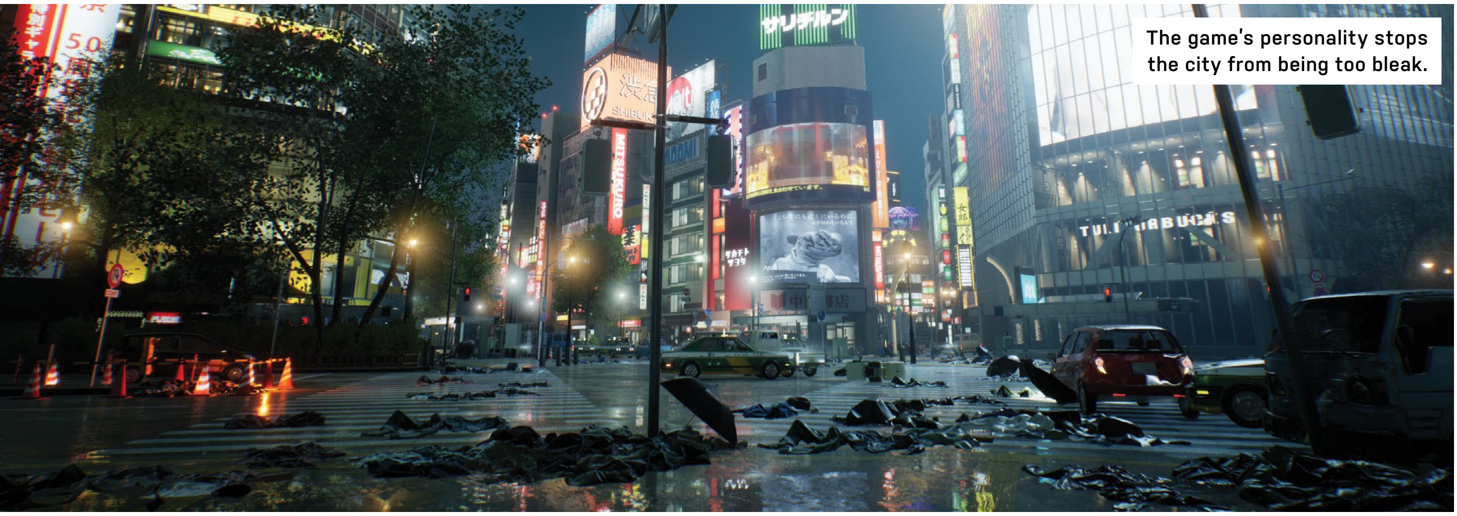
There's a shield for blocking and you can unlock a bow that suffers greatly from limited ammunition in the way the best weapons in survival horror games always do. Upgraded though, it's a beast, taking out enemies with single headshots from the other end of an alley before they even notice you're there. Talismans provide a form of grenade, and fire powers can touch off excellent explosions that open up multiple enemies to having their cores removed.

After last month's *Elden Ring*, which actively wanted to hurt you and took pride in doing so, it's nice to play a game that wants to make you look cool. Akito's ethereal weaving techniques see him snap his fingers into flying shapes that launch a barrage of shapes and colors at the enemy. There are mercifully few boss characters too. Coming from Tango Gameworks, the Shinji Mikami-founded studio behind the *Evil Within* games, there's a definite hint of the mind behind *Resident Evil* here. Thing is, it's the wrong Resi. Rather than 4, which shook up the third-person shooter and made it what it is today, it's the earlier games that seem to have been more of an influence.

TENSION RISING

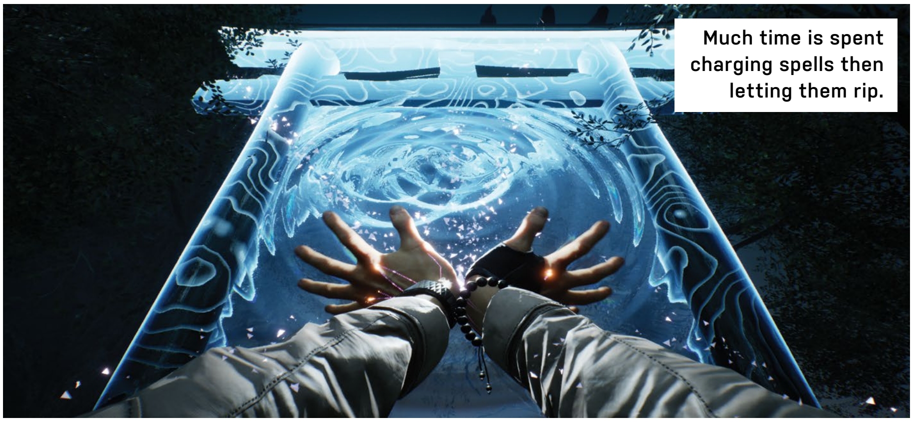
Witness the way characters in *Ghostwire Tokyo* move—the original Resi games built up tension from the knowledge that you couldn't move quickly or freely enough to escape, and as you struggle to turn smoothly here you'd swear the devs are trying the same trick. If there wasn't a lock-on, the game would be considerably more difficult, as you tried to line up an accurate shot on an enemy that's spawned right in front of you with an aiming system that moves in huge chunks rather than the precise slices needed. The weapon-select wheel is sluggish too, its reliability during the more intense combat sequences is open to question.

© BETHESDA SOFTWORKS



The game's personality stops the city from being too bleak.

Pray for world peace? Nah, we're here for extra ammo.



Much time is spent charging spells then letting them rip.

There are no combos or dodges, only a smattering of skill enhancements, repetitive encounters, shallow side missions, and an open world that might as well be from a light-gun game. But what it does have is charm. And collectibles. There are almost a quarter of a million lost souls roaming this empty version of Tokyo and they need to be captured and shut into telephone boxes (obviously) so they can be transferred to the afterlife. Remember when *Assassin's Creed* had you chasing feathers, or *Crackdown* put power orbs just out of reach?

Yet *Ghostwire Tokyo* isn't a bad game. If all you want is to fling fireballs at spooks on a moonlit night in Tokyo, it has a lot to offer. The combat may be shallow but it's fun, the enemies are spooky but interesting rather than scary, and the look of the thing, as you crackle out magical missiles under a wall of neon advertising, is often rewarding enough on its own. It's also full of personality—the floating cats that act as shops, a talking raccoon, and a ghost who just wants some toilet paper see to that—but a lot of this seems shoehorned in to prevent the overall atmosphere from being too bleak.

After all, with the entire population of a megacity reduced to piles of clothes—few of them left behind a wallet or ID to even tell us their names—things could have got a little depressing. As you gradually cleanse the city of a damaging fog, opening up new areas as you do so and discovering shrines at which you can pray for extra ammo capacity (but never any new moves) the weather stays determinedly overcast and the air is filled with the laughter of the ghouls that now stalk its streets.

Most of the plot is crammed into the final third of a not particularly long game, you find yourself rushing through it after you already think the repetitive combat is all the game has to offer. In a way, *Ghostwire Tokyo* feels like a lost member of the Capcom 5, the quintet of GameCube-exclusive supernatural action games that counted *Resi 4* among its number. Only four ever came out, leaving a gap to which the minds of Mikami and his studio appear to have gravitated.

Not particularly scary, a bit repetitive, but a whole lot of dumb fun, *Ghostwire Tokyo* brings these games up to date with modern graphics, but keeps a lot about them the same. It's an enjoyable experiment, but not one we'd expect to be repeated any time soon. **–IAN EVENDEN**

VERDICT
7

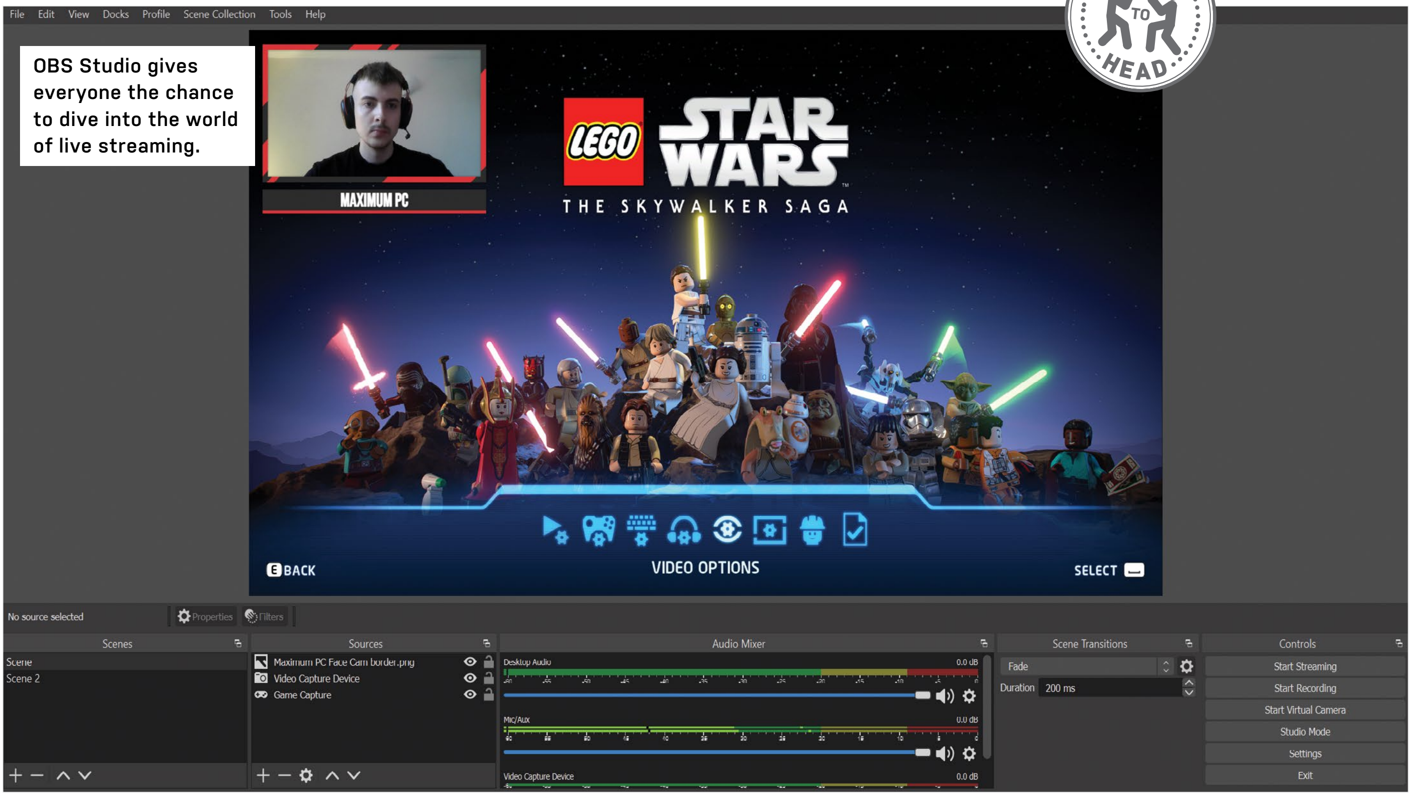
Ghostwire Tokyo

+ MOSTLY Great visuals, crackling combat; imaginative enemies.

– GHOSTLY Repetitive; prioritizes atmosphere over character.

RECOMMENDED SPECS CPU, i7 6700 / Ryzen 5 2600. RAM, 16GB. GPU, GTX 1080 / RX 5600 XT.

$60, bethesda.net/en/game/ghostwire-tokyo


File
Edit
View
Docks
Profile
Scene Collection
Tools
Help
MAXIMUM PC
LEGO
STAR WARS
THE SKYWALKER SAGA
BACK
VIDEO OPTIONS
SELECT
No source selected
Properties
Filters
Scenes
Scene
Scene 2
Sources
Maximum PC Face Cam border.png
Video Capture Device
Game Capture
Audio Mixer
Desktop Audio
0.0 dB
Mic/Aux
0.0 dB
Video Capture Device
0.0 dB
Scene Transitions
Fade
Duration
200 ms
Controls
Start Streaming
Start Recording
Start Virtual Camera
Studio Mode
Settings
Exit

OBS Studio gives everyone the chance to dive into the world of live streaming.

OBS Studio vs. XSplit Broadcaster

Which live stream app is better?

LIVE STREAMING is no longer just a niche corner of the internet, with the huge increase in its popularity over the past decade puhing it to vast global audiences and making it one of the most popular forms of online video. The live aspect of streaming brings in the anticipation and excitement offered by live TV but with the opportunity for anyone to create their own content. Whether it's live streaming games, tournaments, chatting, IRL videos, talk shows, podcasts, music, and even ASMR, there is an almost infinite amount of content available.

As a result, the production side of streaming has gone way beyond just hitting a broadcast button and talking down the microphone—audiences expect more. To stand out from the crowd, you'll need to use live streaming software to polish your content and create a reputable design that oozes quality. Just like high-quality thumbnails on YouTube videos, a well-designed stream layout can bring in viewers. It shows your audience that you've put a lot of time and effort into your stream, just like how making an interesting background in your setup does too.

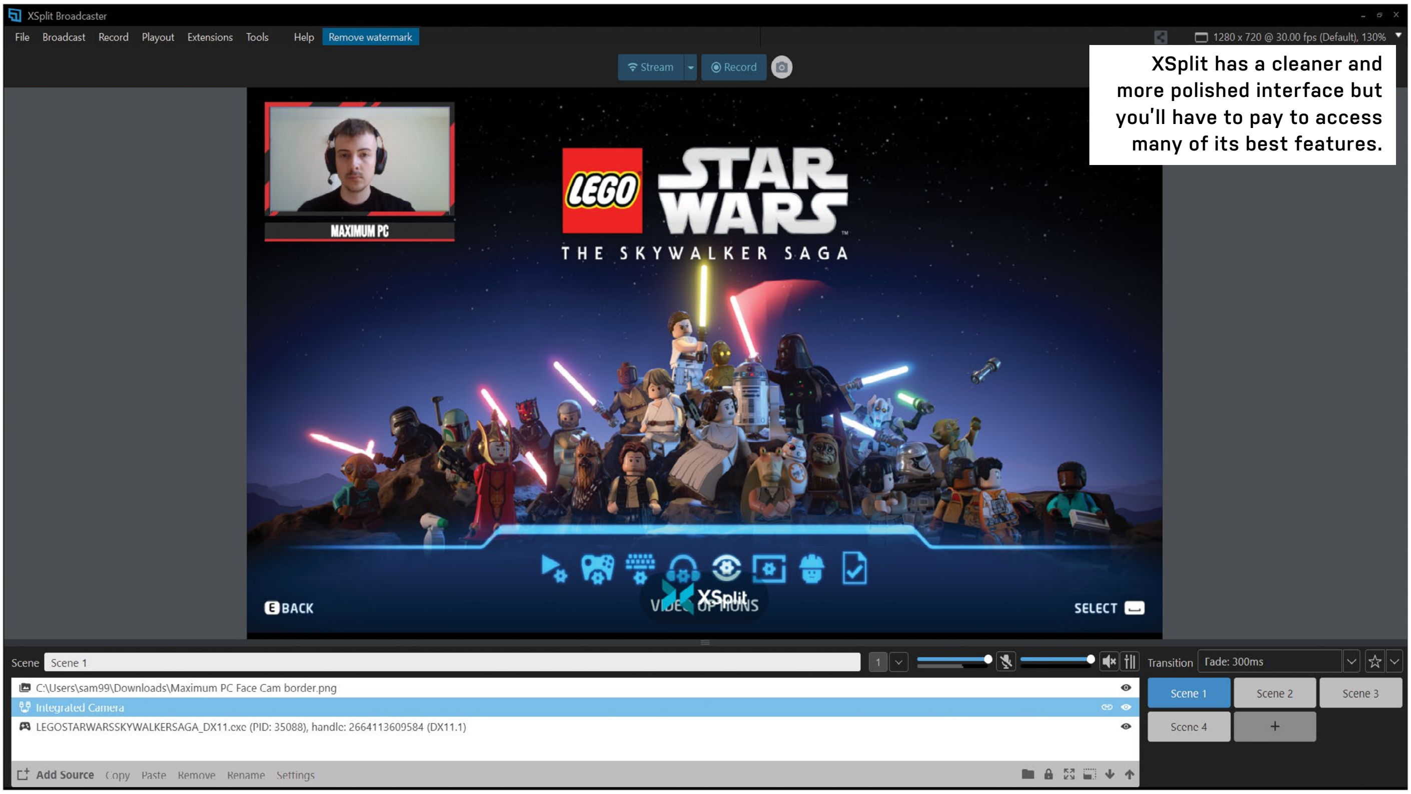
The actual video resolution has to be on par with the visual effects, so using a streaming application can make sure you tweak your stream to your liking. It's a great way to build up an image and style that you may become recognized for. Of course, your content still has to be relevant, engaging, and entertaining—and if it is all three, you won't want to be let down by a low-resolution stream, poor audio, or a basic layout. OBS and XSplit are powerful streaming applications that are more than enough to create a slick-looking stream, so which one should you choose?

If you're new to the streaming world, choosing software could be tricky. You want a program that's quick to pick up and easy to navigate, yet has the potential to be used more intensively down the line. If a program is too heavy and busy from the get-go, it can become overwhelming and even put you off the idea entirely. When jumping into both of these programs, visually, XSplit has a cleaner user interface than OBS. That said, both programs don't have the most striking of designs. The layout on XSplit provides an efficient and simplistic use of space that feels more straightforward than OBS as the latter is more cluttered. Both programs follow a similar layout with the main streaming window in the center of the workspace, your scenes, sources and audio controls below, and the rest of the settings in the top taskbar.

Likewise, with XSplit's design, you have bold buttons to control stream, record, and screen capture at the top, whereas in OBS, these important actions are hidden away in the bottom right corner. When you get more familiar with these, it becomes second nature but, from a beginner's point of view, the most important options should be easily accessible.

Both of these programs fundamentally achieve the same goal. They allow you to capture video from a source or recording and push that to a live streaming service such as Twitch, YouTube, or Facebook Live. In regards to streaming services, OBS has an output of around 90 different streaming platforms, with the ones listed above being just the most popular ones. XSplit, on the other hand, keeps things a bit more focused with 22 sites upon which to stream. So for streaming options, OBS has the upper hand over XSplit, it's just whether or not you will ever use the less popular streaming sites. Thankfully, in both applications, it is easy to link your

© OBS STUDIO



Scene: Scene 1

Transition: Fade: 300ms

C:\Users\sam99\Downloads\Maximum PC Face Cam border.png

Integrated Camera

LEGOSTARWARSSKYWALKERSAGA_DX11.exe (PID: 35088), handle: 2664113609584 (DX11.1)

XSplit has a cleaner and more polished interface but you'll have to pay to access many of its best features.

streaming accounts to the software to live stream quickly. After the first setup, it's as simple as hitting a button, so efficiency is solid for both applications.

To test out the usability of both applications, we tried to create the same simple layout in each—a game recording, with a facecam in the corner and a custom border around it. This is an easy way to make your layout more appealing and to have a nice contrast from your gameplay to your camera. On both platforms, you can create scenes, in which you can edit a design and layout. Then you can create another scene to focus on something else.

For example, we created three separate scenes on each application. The first scene contained gameplay, facecam, and a border around the facecam. The second scene contained the gameplay, and the third scene contained a facecam for closeups and when you are talking to your audience in between games. This is a fairly simple setup and we easily managed to replicate it in both programs. XSplit was slightly more intuitive than OBS again, due to its more simplistic user interface. So, for creating a scene and a layout, XSplit takes another point in this battle.

As for features, both are competitive. There is one initial difference between the two though—OBS Studio is free. Unfortunately, to use XSplit Broadcaster properly, you will need the premium version, which has three options. You can pay monthly at $15, annually for $60, which makes it a more affordable option at $5 a month, or you can buy a lifetime subscription for a one-off payment of $200. Either way, there is still a big cost difference when compared with OBS. There is a free version of XSplit, however, your videos will be watermarked if you don't pay, and you're limited to a maximum of four scenes. As you'd expect, most of the best features are hidden behind a paywall—the premium version offers a much richer program, including multi-streaming, unlimited resolution, unlimited scenes, source transitions, projector mode, and more.

As for what OBS offers for free, there is no watermark and you can achieve the same outcome, it just takes slightly longer and isn't as clear-cut as XSplit. The question is then, is XSplit worth paying monthly for over OBS? This depends on what level you are as a streamer. If you stream for fun and games and see the activity as a hobby, then OBS is all you'll need. It's still a capable and powerful program, and for the most part, is fairly simple to use.

On the flip side, the outdated and raw design hinders the application and means it's not as user-friendly as XSplit Broadcaster. If you're using this program frequently and taking live streaming down a more commercial route on Twitch or YouTube, then XSplit would be our choice. As you'll be using it more frequently, the easier-to-use application will certainly help with efficiency and reward you in the long run.

So which one is the winner? The short answer is OBS, although it is marginal. We aren't fans of the application's basic design but it offers many of the same features as XSplit, only without the cost. XSplit won't break the bank, but why have yet another subscription service taking a monthly bite out of your bank balance when there's a free alternative? Both apps have powerful editing tools, can create high-resolution streams, and broadcast to a multitude of services. It just depends on what type of streamer you are. **–SAM LEWIS**

VERDICT 8

OBS Studio

OBYES Open-source community; simultaneous recording and streaming; free.

OBNO Raw design style; overwhelming at first.

Free, www.obsproject.com

VERDICT 7

XSplit Broadcast

XCELLENT User friendly interface; stream delay feature; clean design; appropriate for both gaming and business.

SPLIT OPINIONS Watermarked and only four scenes (free version); most of the best features hidden behind paywall.

XSplit Broadcast, free. XSplit Broadcast Premium, $15/month, $20/annually or a one off payment of $200. www.xsplit.com

© XSPLIT BROADCASTER

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Keeping a Low Profile
> Unclear Windows
> RAM Raider
> Desktops vs. Laptops

Logitech's Pro TKL Gaming Keyboard is a great all-rounder.

Tackling TKLs

I feel that you missed a few important items in your review of the MSI Vigor GK50 Low Profile TKL in the March 2022 issue. Now, I'm no expert, but I'm sure adherence to functional consistency and standardization are paramount to a keyboard's success and usability.

I am versed enough to have experienced proper QWERTY keyboards (even TKLs), where the individual key's functions are arranged vertically, so the normal function is the bottom character, and the shifted key function is the upper one. This allows for easy comprehension of functional operation.

Lately, I've seen many keyboards (including the TKL I'm typing on now) where the key characters are arranged horizontally and the functional operation is left to right (the left character is default and the right is the shifted one).

It's no big deal if the entire keyboard chooses one or the other, as long as it is consistent throughout. However, the MSI not only switches from the former to the latter for portions of the board but looking at the number keys, reverses the normal left to right shift standard, to a right with left shift function per key. What a dog's breakfast!

Secondly, there is the standardization aspect. From the image in your review, the keys are laid out in some form of adulterated QWERTY, with the Tilda and pipe key combined, and the left shift cut down to make room for the backslash combo (normally found on the right side of the board).

Had I not noticed these issues in the keyboard image in your review, I would have agreed with the 7 verdict or thought it even higher. But since you missed these issues, which to me are deal-breakers, I feel this keyboard should have deserved a lower rating. Still love your mag though, keep up the good work! **–M. Maser**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Sam's review of the MSI keyboard led to me compiling a list of the best TKL keyboards for the following issue (April 2022), and I asked Sam if I could borrow the MSI to compare to other keyboards in the roundup. Sam was kind enough to let me keep it, as I found typing on a low-profile board more comfortable than standard full-size keycaps.

Perhaps it's being used to laptop keyboards, or not having to lift my fingers as high, but whatever it is, I'm more accurate and productive on a low-profile board. I'm a total convert and would probably have scored it an 8 if I were reviewing it personally.

That was until I read your letter, however, and noticed what a nightmare it is from a consistency standpoint! Because I'm so used to using keyboards and knowing mentally what each key's default and alternative function is, I admit I hadn't properly examined it from a design perspective.

However, I agree that consistency should have been applied and that the result here will probably drive a lot of people crazy!

In terms of your issue with the general layout of the board though, I have no complaints as it's the same as many other boards I've used, although there could of course be territorial differences (I note you write from Canada).

↘ submit your questions to: editor@maximumpc.com

Thanks very much for pointing the inconsistencies of this board out though, and it's something I'll keep an eye out for in future. In the meantime, I'll point you towards Logitech's G915 TKL, which I've also been using—it's much more consistent, but it's a wireless board and will cost you an eye-watering $210. But hey, no one said good design was cheap!

The Key, The Secret

I'm a long-time reader all the way back from *Boot* issue #1 and I just wanted to write in and point out that with the latest issue's $1300 build and last issue's budget build, there was no cost factored in for a Windows license. However, in the part of the build instructions where the OS is mentioned, it's spoken of as an essential. Sure, we can use a free Linux OS, but that's not mentioned, and leaving that cost out is misleading for the total given. All in all, thanks for a great magazine that as long as it's still in print (paper!), I'll be a subscriber.

–M. Whiteford

The builds in the back all have Windows Home for $32. Where do you get that? I have yet to find it available at any place for less than $95. If Home is $32, then pro would be only $75. I would love to find Windows Pro for $75! **–S. Kurt**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: I've had quite a few questions about Windows 10/11, how we price it up, and where we get the $32 figure from in our Blueprint section. Apologies if it hasn't been clear until now.

If you go to a big box retailer or online store then it will cost around $100-120 to get Windows on a DVD or USB Flash Drive. However, as *Maximum PC* readers, we assume you're comfortable with making your own installation media and then simply buying a license.

Buy or reuse a USB stick (at least 8GB) and head to www.microsoft.com/en-us/software-download/windows11 to create your installation media.

To purchase the license, head to a reputable online key retailer such as G2A.com or Gamivo.com, and you'll find Windows 11 Home for around $32, and Windows 11 Pro for $60. It's also worth reminding you that if you already have a Windows 10 license, you should be able to activate Windows 11 for free.

If you're upgrading or building a new system, there's a chance it might not work during installation, but you can still install the operating system and then contact Microsoft for help if needed. I've personally had to do this before and found Microsoft to be very helpful.

Wham! Bam! Thank You RAM

I'm finally going to pull the trigger on building a new PC. I'm just going to upgrade my motherboard, CPU, cooler, and memory. I hate slowness and want to be able to push game settings to maximum, so I was going to get a Core i9 and 64GB or 128GB of RAM. I will be gaming, photo editing, and maybe video editing. Is this amount of RAM too much? Should I consider an Intel Core i7 chip? Or go AMD? I need advice! **– L. Keel**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Congratulations on upgrading your PC! The questions you've asked are what every PC builder goes through. Essentially, your core challenge seems to be: what components do I need to spend the most on?

I've made some assumptions based on the information you've given me, the biggest of which is that I don't know what GPU you're going to be using. This is most relevant to your wish to game at max settings— in that case, you'll want an Nvidia RTX 3090 Ti or AMD RX 6900 XT. However, I would suggest reading our GPU feature on page 26. It tells you why you don't need to game at ultra and why you'd get much better bang for your buck elsewhere.

In terms of memory, for gaming, the returns diminish above 32GB, and 16GB is still more than enough for most games. Photo and video editors always love having more memory though, so there could be an argument for going for 64GB if this is the main purpose of the machine.

It's the same advice for the processor—the i9-12900K will tear through your creativity tasks, but the i7 saves you at least $150 and only the most hardcore of 4K editors will see the difference. Even the i5-12600K, which is less than half the price of the i9, is good enough for most, including gamers.

On the AMD question, the high-end Ryzen 9 5950X is a good match for your i9, but it's a year older and doesn't support DDR5 RAM. Not a big issue right now, but something to think about for the future.

I hope this helps, and enjoy your new PC!

Dreaming of Desktops

Hello! I'm 13 years old and have loved PCs ever since I was 11. I've never had a desktop PC and I have to wait a year to get a job in North Dakota to buy one, sadly. But that brings me to my question: what will be different on a desktop over my current gaming laptop? I'm running an Acer Nitro 5 with a Core i5 11th gen CPU, an Nvidia GTX 1650, and Windows 11.

My second question is could you write about this AI aimbot that claims to be "undetectable". My main game is *Valorant* and I want to know how worried I should be. I love the hard work that goes into the magazine. Thanks for your time! **–J. Arndt**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: It was a pleasure to read such a well-written letter from the next generation of PC user. I can remember getting into PC gaming at the same age, although that sadly feels a long time ago now!

To answer your question on laptop vs. desktop, the benefits of a desktop tend to be that you can get more power for your money, plus the improved airflow and cooling options will allow you to overclock your components.

In your case, though, I'd stick with what you've got, or upgrade your laptop when you have the funds to do so. Assuming you also use the laptop for school and internet browsing, you have a more portable option in the Acer Nitro 5, and if you're mainly playing *Valorant*, you don't need anything more than the system you already have. Check out our review of the new 2022 Acer Nitro 5 on page 80, or the Lenovo Legion 5 Pro on page 82, to see what this year's mid-range laptops can do.

On *Valorant* or any other online game, cheaters will always try their luck sadly. Riot does a good job of detecting and banning cheaters through its Vanguard anti-cheat system, and last year, a Swedish eSports platform called G-Loot used AI to detect player inputs.

I believe the latter is the future of fraud detection in online gaming and should be both more accurate and faster at detecting the bad actors than manual reporting.

© LOGITECH

THE BUILDS

THIS MONTH'S STREET PRICES...

BUDGET

WE'VE SEEN SOME price increases on components this issue, starting with a $10 hike on the Corsair 4000D Airflow case that houses both of these builds. The CV550 80+ Bronze power supply (also from Corsair) is back up to $50, so we've added an alternative in the same price range for the AMD system: Asus's TUF Gaming 550W PSU, which touts its 'military-grade' specs. This should perform as well as the Corsair one and comes with a six-year warranty.

The Gigabyte B550 mobo in the AMD build is listed at $130 in our parts table, but you may be able to pick one up for less. Meanwhile, the Intel machine gets a new B660-chipset motherboard from MSI, the Pro B660-M, which is more expensive but offers a superior port selection to the B660 board from ASRock we used in previous issues. We're sticking with the processors found in both builds as there was little price fluctuation; we considered bringing additional integrated graphics to the Intel build, but the i5-12400F is cheaper than the UHD-equipped 12400, and testing has indicated a slightly better performance in single-core workloads.

While some parts are pricier this month, budget GPUs continue to fall. Sales saw us nab an XFX Speedster SWIFT210 RX 6600 XT for the AMD machine and an MSI Ventus RTX 3050 for the Intel. Although these cards are still pricey, we found both for less than $100 above their original RRP. We added new memory to the AMD build, namely Corsair's Vengeance LPX at the budget build's usual 16GB, 3600MHz, CAS latency 16 specs. At $75, it's a great deal.

Lastly, we looked into new drives across the board in our budget builds this month, but having added new SSDs to both machines last time, we were already pretty comfortable with the storage in these systems. Both SSDs and the WD Blue HDD we're using dropped in price by a small amount this month, so we'll leave that hardware where it is. Overall, we dropped the total cost of both budget machines by a small amount, which we're pleased with.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	$95	
PSU	550W Asus TUF Gaming 80+ Bronze **NEW**	$50	
Mobo	Gigabyte B550 Aorus Elite AM4	$130	
CPU	AMD Ryzen 5 5600X	$229	
GPU	XFX Speedster SWIFT210 Radeon RX 6600 XT 8GB **NEW**	$379	$430
RAM	16GB (2 x 8GB) Corsair Vengeance LPX CL16 @ 3600MHz **NEW**	$75	
SSD	500GB MSI Spatium M450 PCIe 4.0 M.2 SSD	$55	
HDD	4TB WD Blue 5400 HDD	$54	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32	

Approximate Price: $1,099 / $1,150

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	$95	
PSU	550W Corsair CV550 80+ Bronze	$41	
Mobo	MSI Pro B660-M **NEW**	$130	
CPU	Intel Core i5-12400F	$180	
GPU	MSI Ventus GeForce RTX 3050 8GB **NEW**	$249	$330
RAM	16GB (2 x 8GB) Kingston FURY Renegade CL16 @ 3600MHz	$91	
SSD	500GB Team T-Force Cardea Graphene Z44L PCIe 4.0 M.2 SSD	$55	
HDD	4TB WD Blue 5400 HDD	$54	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32	

Approximate Price: $927 / $1,008

MID-RANGE

WE DIDN'T CHANGE the power supplies found in our mid-range systems this month because the NZXT C750 and EVGA SuperNOVA 750 GA remain the best-value PSUs available at this wattage. At the time of writing, you can buy the C750 for just $40, but only if you have all the power cables you need since this one comes without.

Both systems keep their processors for now but the AMD build gets a new motherboard, the X570 Gaming X from Gigabyte, an absolute steal at $130. The Intel rig keeps its Asus Prime mobo, thanks to an excellent sale that drops the price by more than $40 from RRP. For $3 more, you can upgrade to the WiFi-enabled version of that Asus board; a potentially savvy decision for future-proofing your build even if you currently have easy Ethernet access.

A sale on Raijintek's Orcus 240 RBW all-in-one liquid cooler prompted us to use it in the AMD system this month, with the price dropping from $110 to $80. This cooler also has addressable RGB fans and pump block, which is a nice extra but it doesn't have LGA 1700 socket compatibility, so wouldn't have worked in the Intel build. Instead, that retains the Corsair H100i cooler (no longer on sale).

Joining the AMD build's new arrivals this month is the Sapphire PULSE Radeon RX 6800 XT, cheaper than the previous 6800 XT we were using last month. Prices of mid-to-high-end GPUs seem to be easing, though not as quickly as budget cards. The Intel system gets an RTX 3070 from EVGA, which is also cheaper than last month's Asus TUF model but not as much of an expense drop as the 6800 XT.

We're making one last big change to our midrange builds in this issue: an upgrade to 32GB of total RAM. This will increase the total price, but falling GPU prices and greater performance from current-gen CPUs with access to more memory inspired us to make the switch. The AMD system gets the discounted Kingston FURY Renegade RGB, while the Intel system sticks with the Corsair Vengeance RGB RT (while upgrading to 16GB per stick, of course).

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	$183	
PSU	750W NZXT C750 80+ Gold	$90	
Mobo	Gigabyte X570 Gaming X **NEW**	$130	
CPU	AMD Ryzen 7 5800X	$349	
Cooler	Raijintek Orcus 240 RBW ARGB **NEW**	$80	
GPU	Sapphire PULSE Radeon RX 6800 XT 16GB **NEW**	$649	$859
RAM	32GB (2 x 16GB) Kingston FURY Renegade RGB CL16 @ 3600MHz **NEW**	$150	
SSD	500GB Samsung 980 Pro NVME M.2 PCIe 4.0 SSD	$102	
HDD	4TB WD Blue 5400 HDD	$54	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32	

Approximate Price: $1,819 / $2,029

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	$183	
PSU	750W EVGA SuperNOVA 750 GA 80+ Gold	$95	
Mobo	ASUS Prime Z690-P LGA 1700	$188	
CPU	Intel Core i7-12700F	$313	
Cooler	Corsair iCue H100i RGB Pro XT 240mm	$72	
GPU	Asus TUF Gaming GeForce RTX 3070 8GB **NEW**	$499	$713
RAM	32GB (2 x 16GB) Corsair Vengeance RGB RT CL16 @ 3600MHz **NEW**	$157	
SSD	500GB Corsair Force MP600 M.2 PCIe 4.0	$81	
HDD	4TB WD Blue 5400 HDD	$54	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32	

Approximate Price: $1,674 / $1,888

BOTH OF OUR HIGH-END processors saw price hikes this month, though not disastrously so. We're keeping both CPUs, although if you're willing to sacrifice integrated graphics you could save a few bucks by opting for the i9-12900KF in the Intel build. Good Z690 motherboards remain expensive, but we were happy to see $10 shaved off the price of the MSI mobo in our Intel turbo system. Conversely, the Gigabyte X570 Aorus Elite WiFi rose by the same amount but remains good value for money for an X570 board.

The AMD turbo build gets a new power supply and a new CPU cooler—the Cooler Master MWE 850 V2 and NZXT Kraken X72, respectively. This PSU brings the AMD system up to 850W of total power, bringing it in line with its Intel counterpart. That NZXT AIO is on sale at the time of writing, making it cheaper than the LGA 1700-compatible MSI MAG AIO cooler we've added to the Intel rig this month. Neither machine got a new GPU, because both the ones we had in place dropped by over $100. The semiconductor shortage is finally easing, with graphics card stock coming home to roost.

With our bump from 16GB to 32GB of RAM in the mid-range builds, it seemed appropriate to put those GPU savings to good use here too, so both systems are getting an upgrade to a hefty 64GB of memory. The AMD build sticks with DDR4, getting G.Skill's RGB-illuminated Trident Z Neo kit at 4,000MHz. The Intel system forgoes colored LEDs in order to keep the price down with a Corsair Vengeance kit. DDR5 is still expensive, even more so when looking at 64GB kits, so stick to 32GB if you want to save some cash.

HDD storage (particularly at lower RPMs) seems to be getting cheaper, with Western Digital's 6TB Blue drives dropping to $80. PCIe 4.0 SSDs at higher capacities are getting cheaper too, with the excellent Samsung 980 Pro 1TB on sale for $130. The AMD build gets this M.2 drive, while the Intel turbo system enjoys a WD Black SN850 to match its hard drive. While our doubled-up RAM raised the cost of these builds, savings elsewhere meant that the overall prices totals didn't increase much, so we'll consider that a win.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$190	
PSU	850W Cooler Master MWE V2 80+ Gold **NEW**	$100	
Mobo	Gigabyte X570 Aorus Elite WiFi	$190	
CPU	AMD Ryzen 9 5950X	$650	
Cooler	NZXT Kraken X72 360mm **NEW**	$130	
GPU	ASRock Radeon RX 6900 XT Phantom Gaming D 16GB	$999	$1,150
RAM	64GB (2 x 32GB) G.Skill Trident Z Neo DDR4 @ 4000MHz CL18 **NEW**	$340	
SSD	1TB Samsung 980 Pro M.2 PCIe 4.0 **NEW**	$130	
HDD	6TB WD Blue 5400 HDD	$80	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32	

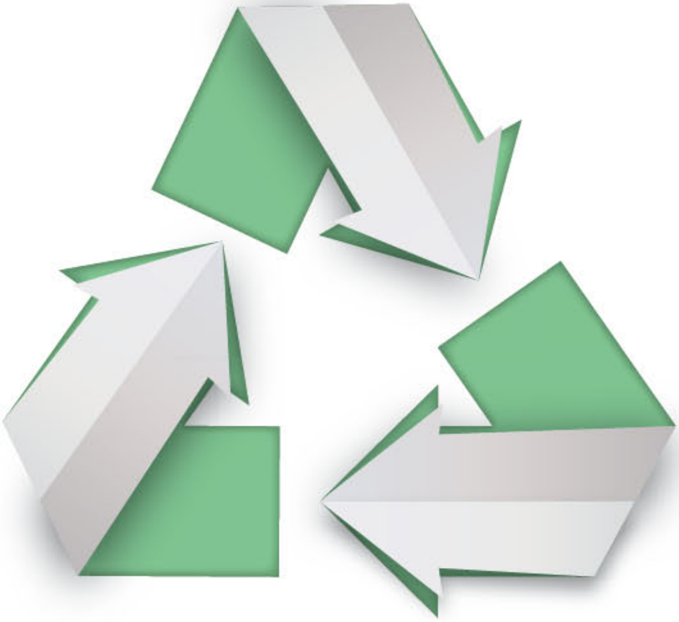
Approximate Price: $2,841 / $2,992

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$190	
PSU	850W Corsair RM850 80+ Gold	$118	
Mobo	MSI PRO Z690-A WiFi LGA1700	$240	
CPU	Intel Core i9-12900K	$610	
Cooler	MSI MAG CoreLiquid 360R V2 360mm **NEW**	$140	
GPU	EVGA GeForce RTX 3090 FTW3 Ultra Gaming 24GB	$1,500	$1,700
RAM	64GB (2 x 32GB) Corsair Vengeance DDR5 @ 5200MHz **NEW**	$565	
SSD	1TB WD Black SN850 M.2 PCIe 4.0 **NEW**	$137	
HDD	6TB WD Blue 5400 HDD	$80	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$32	

Approximate Price: $3,612 / $3,812

Maximum PC (ISSN 1522-4279) is published 13 times a year, monthly plus a Holiday issue following the December issue, by Future US, Inc., 10th floor, 1100 13th Street, N.W Washington DC 20005, USA. Website: www.futureus.com. Periodicals postage paid at New York, NY, and at additional mailing offices. Newsstand distribution is handled by Curtis Circulation Company. Basic subscription rates: one year (13 issues) US: $30; Canada: US$30; Foreign: US$50. Canadian and foreign orders must be prepaid. Canadian price includes postage and GST (GST #R128220688). PMA #40612608. Subscriptions do not include newsstand specials. POSTMASTER: Send changes of address to *Maximum PC*, PO Box 2024, Langhorne, PA 19047, USA. Future US, Inc. also publishes *MacLife*, and *PC Gamer.* Entire contents copyright 2021, Future US, Inc. All rights reserved. Reproduction in whole or in part is prohibited. Future US, Inc. is not affiliated with the companies or products covered in *Maximum PC*. Reproduction on the Internet of the articles and pictures in this magazine is illegal without the prior written consent of *Maximum PC*. Products named in the pages of *Maximum PC* are trademarks of their respective companies. PRODUCED IN THE UNITED STATES OF AMERICA.



PAPER REVOLUTION

Over 66% of paper and paper-based packaging in the U.S. is recycled into new products, one of the highest recycling rates of any material in the country.

Discover the story of paper
www.lovepaperna.org

LOVE PAPER ®

Sources: American Forest and Paper Association, 2019
U.S. Environmental Protection Agency, 2017

Love Paper is a registered trademark for Two Sides Ltd. Registered in the U.S., UK and other countries and used with permission.

PC GAMER
EDITOR'S CHOICE
★★★★★
MAXIMUM PC
KICK ASS!

We build the world's most advanced PCs.

Experience a new level of performance with an award-winning Digital Storm PC. Built with the latest technology, highest quality components and backed by lifetime support. Visit our website and build your dream PC today.

DIGITALSTORM

LEARN MORE: WWW.DIGITALSTORM.COM
Digital Storm PCs featuring Intel® Core™ i7 processors.

The Digital Storm Logo, and 'World's Most Advanced PCs' are trademarks of Digital Storm. Intel, the Intel Logo, Intel Inside, Intel Core, and Core Inside are trademarks of Intel Corporation in the U.S. and/or other countries.

9027
9000